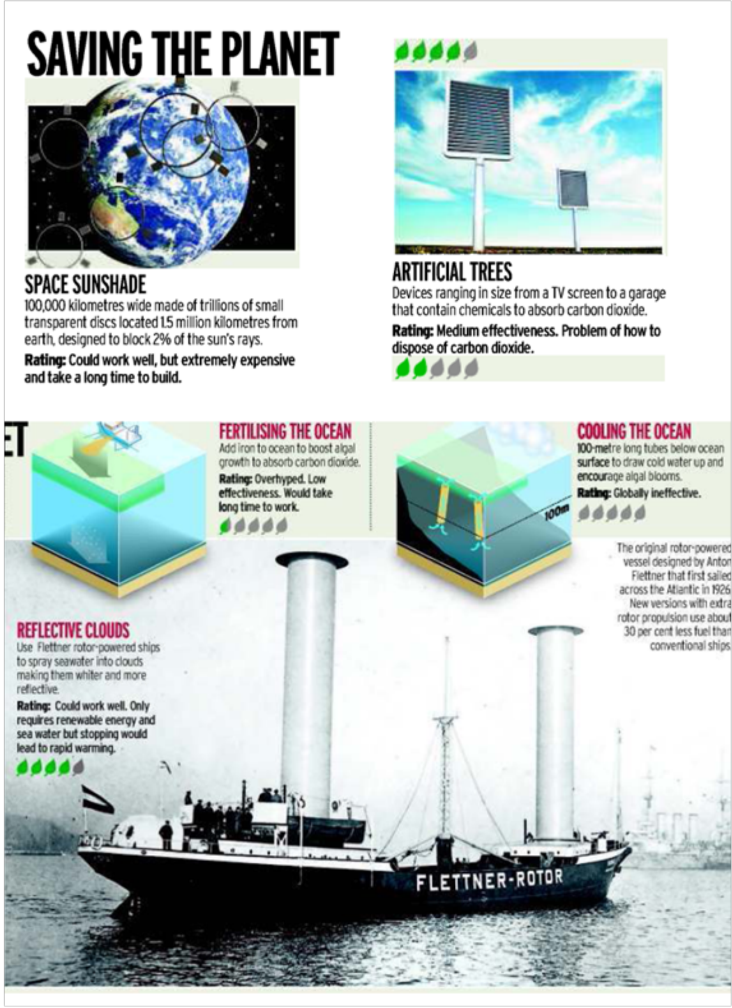
Ranking criteria for geo-engineering schemes



Philip Boyd

NIWA

USING COMPLEX DECISION-MAKING TOOLS TO EVALUATE DIFFERENT GEOENGINEERING SCHEMES

the ROYAL SOCIETY of NEW ZEALAND
TE APĀRANGI

Outline

Geoengineering & Donald Rumsfeld

What ranking criteria to use?

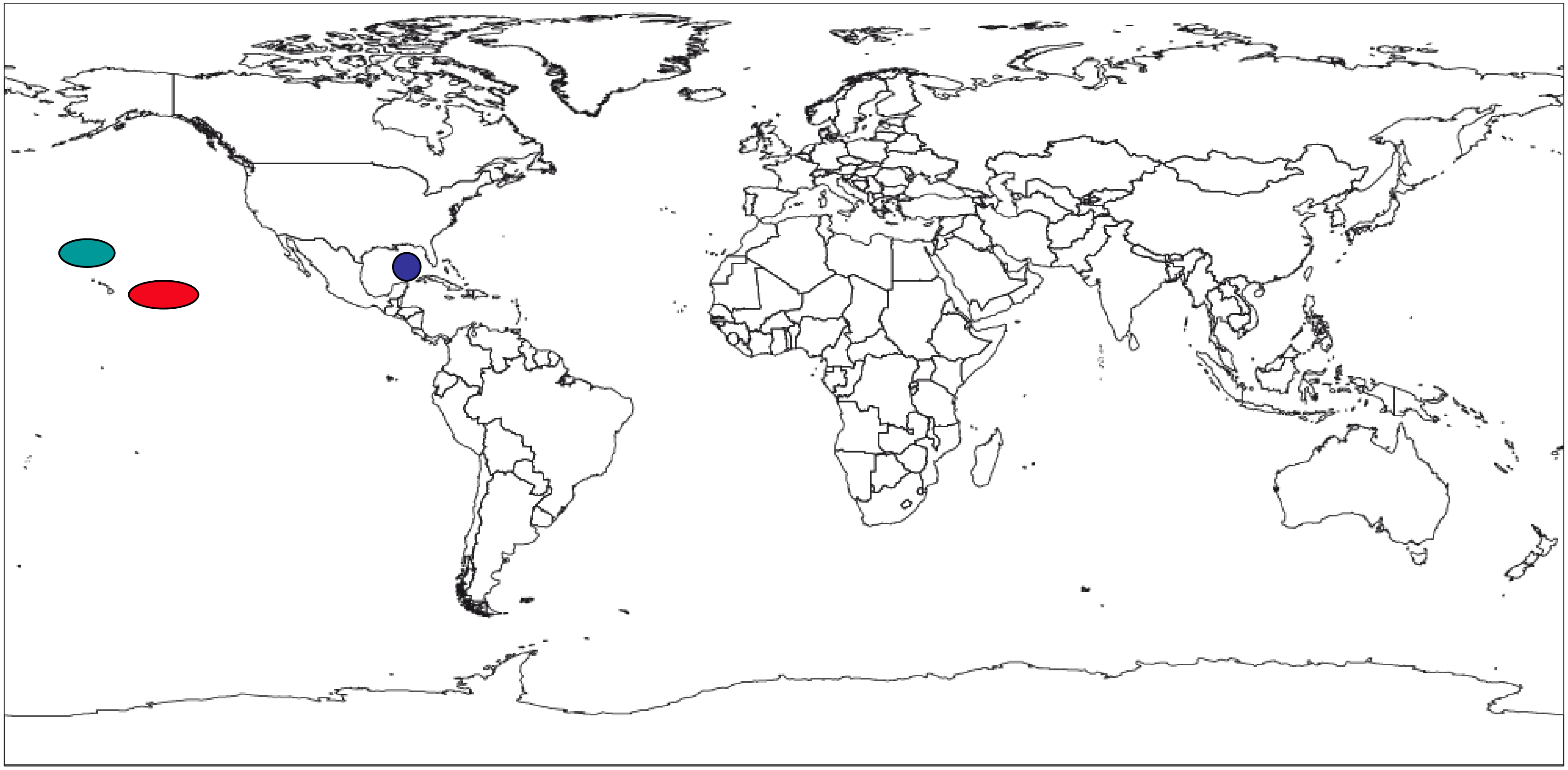
How to assess? – something out of nothing

Geoengineering & Donald Rumsfeld

"There are known knowns; there are things we know we know.
We also know there are known unknowns; that is to say we know there are some things we do not know.
But there are also unknown unknowns –
the ones we don't know we don't know."

—Former US Secretary of Defense Donald Rumsfeld

Geoengineering oceanic pilot studies and other trials

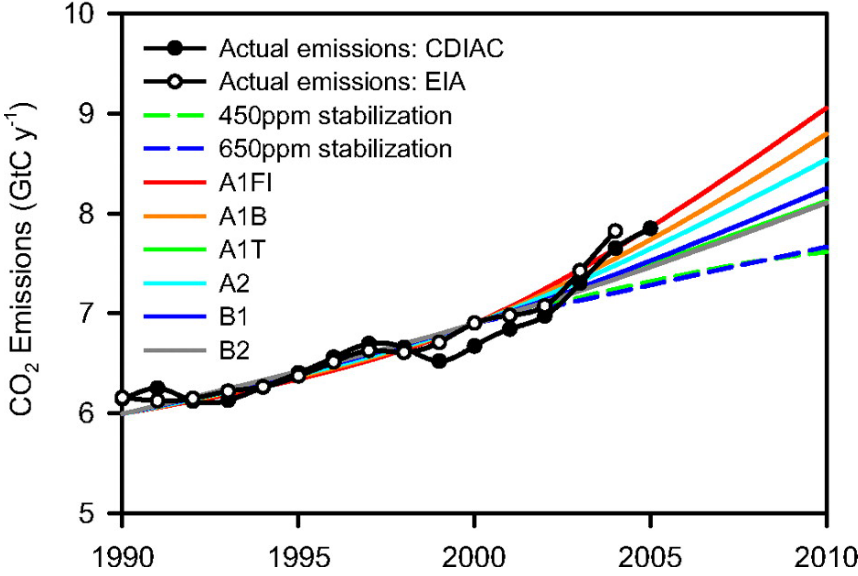


June 2008 Trial of Controlled Upwelling Using Wave Pump Technology

Summer 2002 Planktos – release of iron-containing paint pigment along a 50 km swathe of ocean

Spring 1998 Green-Sea Venture two 9 km^2 trials of iron fertilization

What ranking criteria to use?



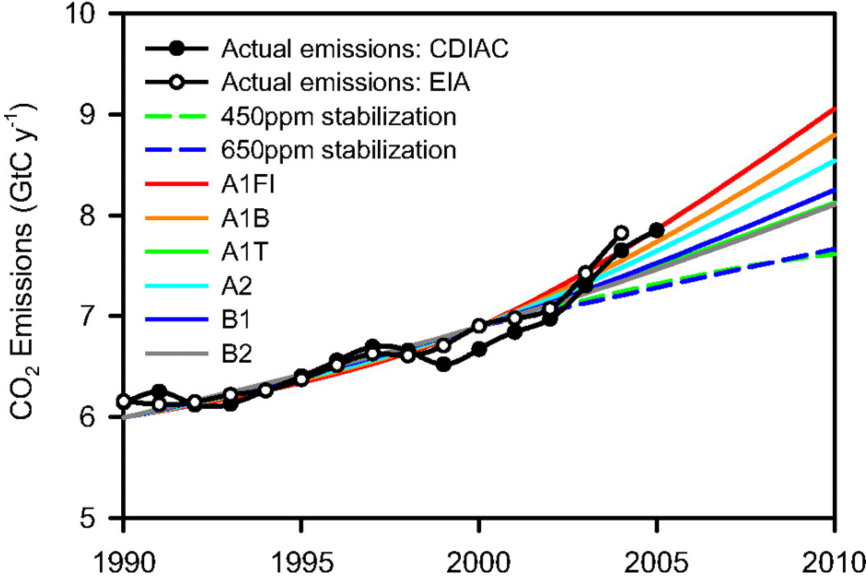
Scientific - likelihood of success, how well will they offset rising temperatures?

Ethical - should we tamper with the Earth system unless we have a foolproof method?

Economic - will they be prohibitively expensive?

Geo-political - will they cross international boundaries?

What are the aims of using Scientific ranking criteria



- ❑ to provide knockout criteria to offer a rigorous initial appraisal of all geoengineering methods

- ❑ to identify the most promising methods which can then be further tested, and their pro’s and con’s examined

- ❑ to compare and contrast what the best method offers relative to doing nothing

- ❑ to construct a climate-change tool box

How to assess? – something out of nothing

Given the dearth of information or data on different geoengineering methods

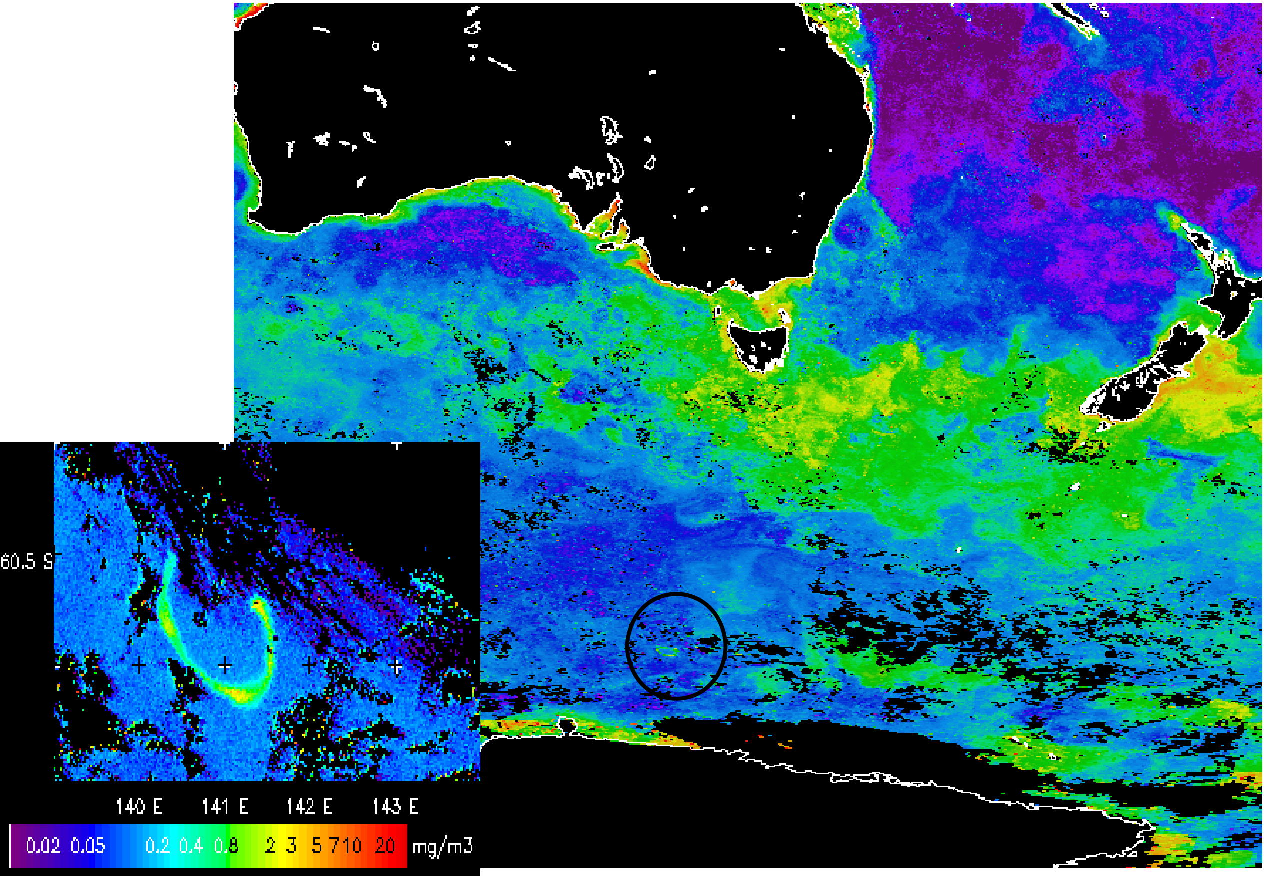
How can we accurately rank different schemes?

1) **Using other scientific studies as proxies**
2) **Employing present day examples of natural perturbations**
3) **Investigating episodes of marked change in the geological past**
4) **Exploiting theoretical and modelling datasets**

Using other scientific studies as proxies

Indirect evidence – from mesoscale iron-enrichments

These experiments were not geoengineering trials but public sector funded scientific experiments to investigate climate science questions



The studies were:

Mesoscale (50 to >1000 km^2)

Multidisciplinary

Supported by satellite Remote-sensing

Published in the peer Review literature

Employing present day examples of natural perturbations

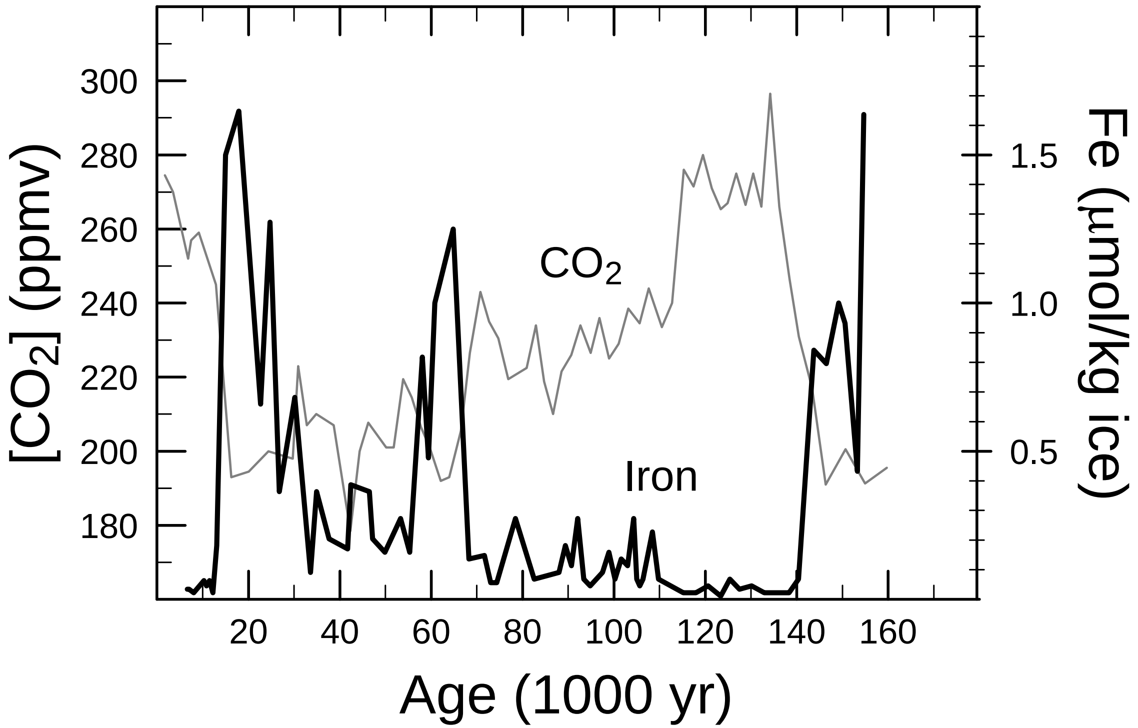
Large scale volcanic eruptions
How does the
earth system respond

Direct effects

Indirect effects

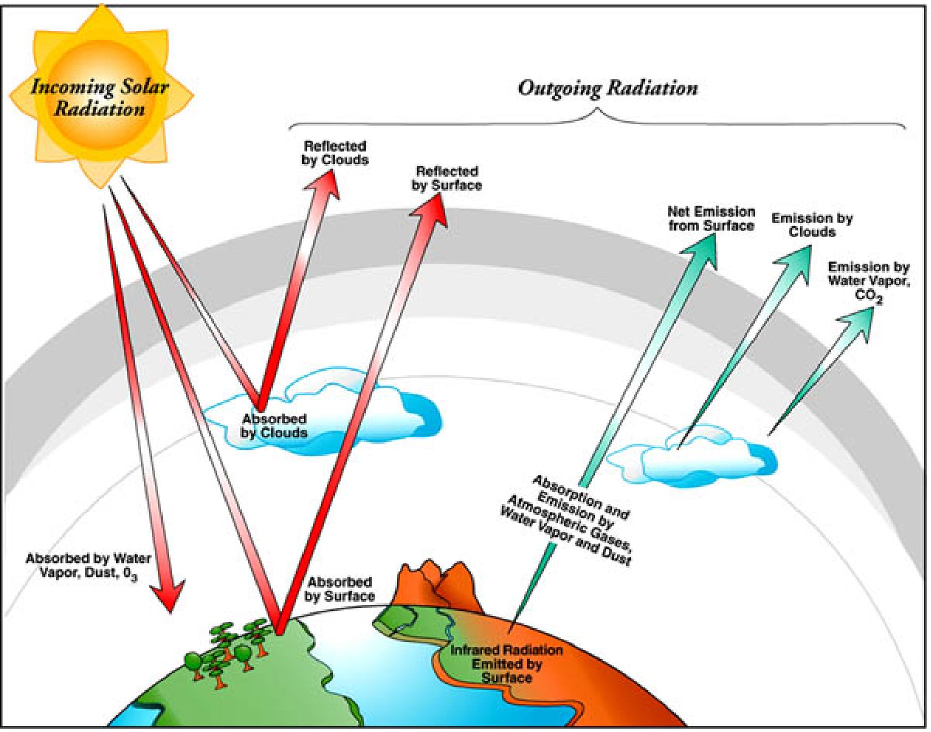
Timescales of effects

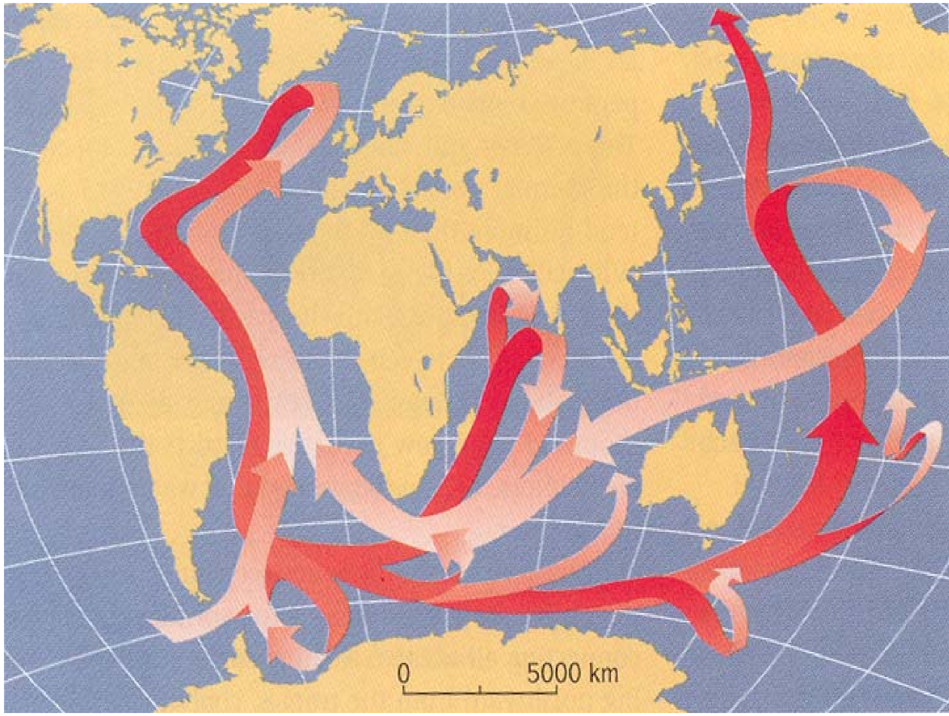
Investigating episodes of marked change in the geological past



What were the drivers of changes in atmospheric [CO_2] in the distant past?

Exploiting theoretical and modelling datasets





Two fundamentally different ways to cool the planet

Ocean vs. atmospheric residence time

Only one of these also addresses Ocean acidification

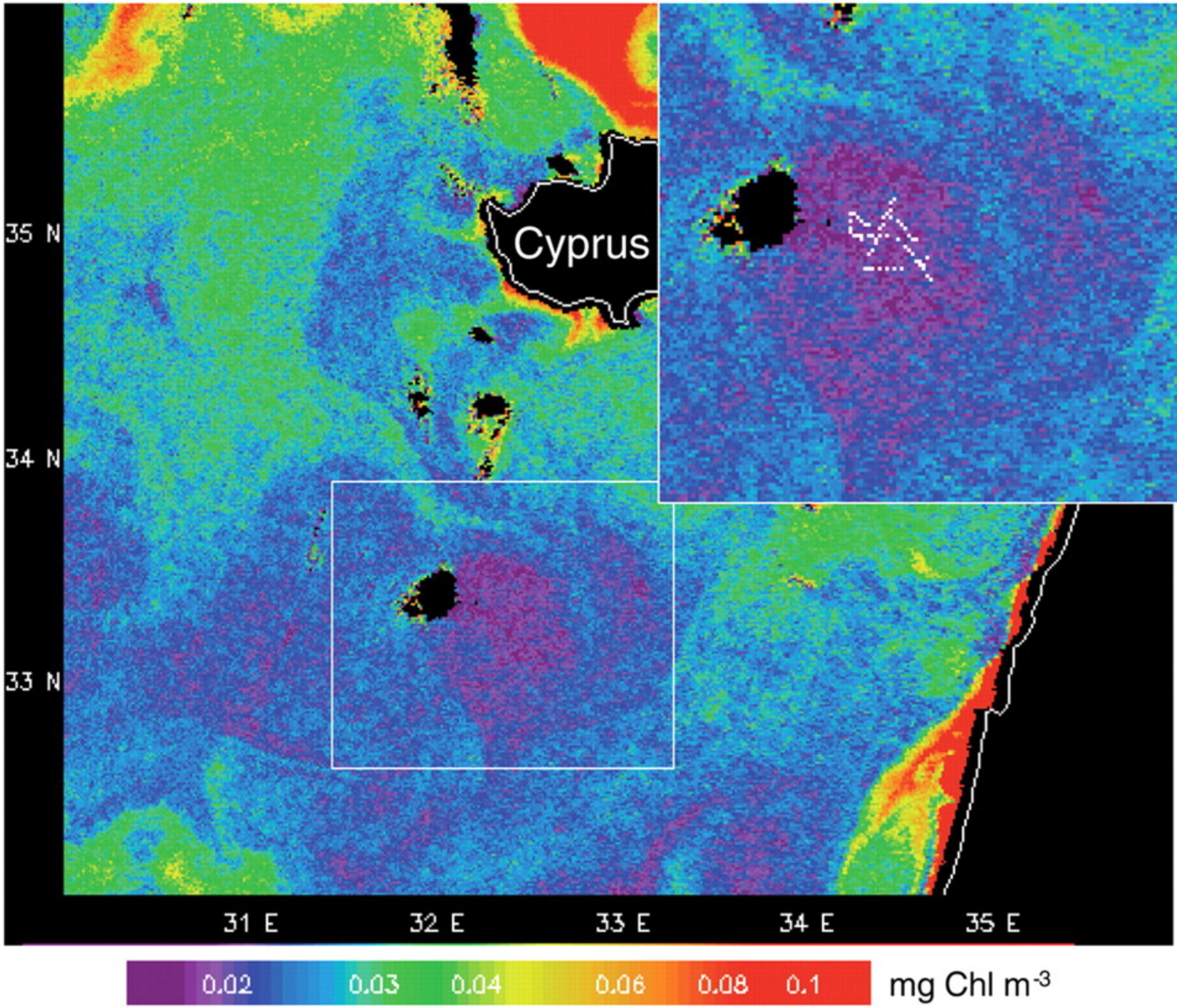
What have we learnt to date from proxies, natural perturbations & modelling?

The biota when perturbed on't always behave properly

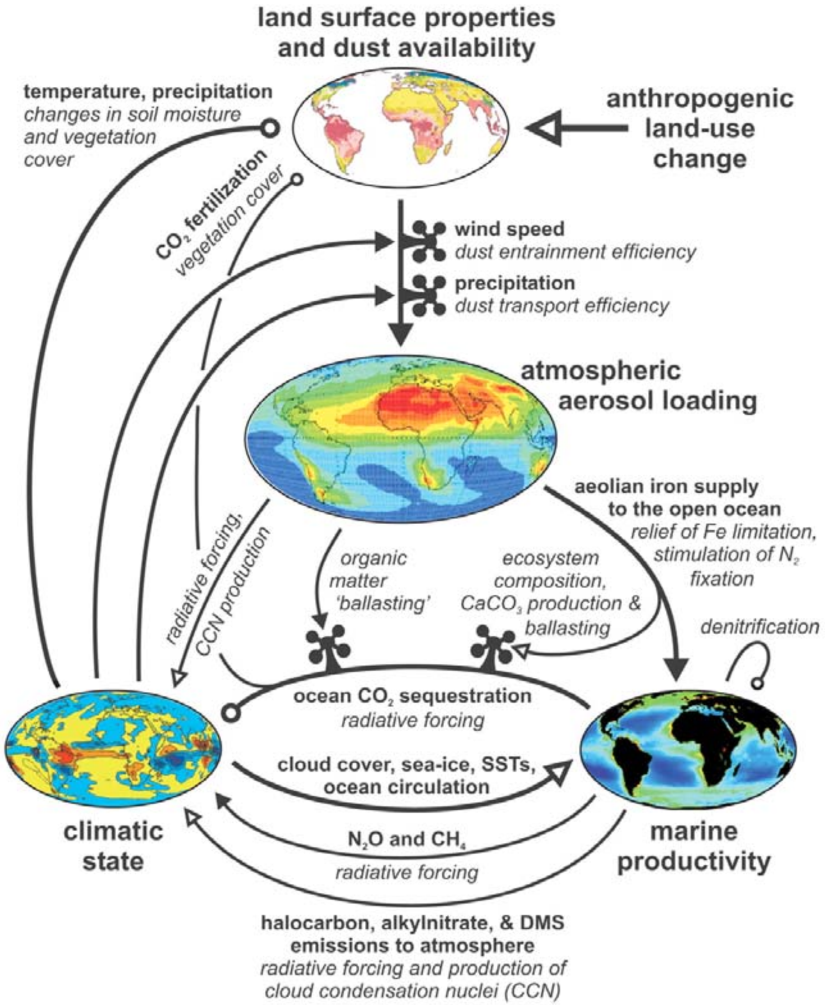
Unanticipated

Side-effects

Can occur



The Earth System is a complex circuit diagram – with knock-on effects



Pinatubo also caused:

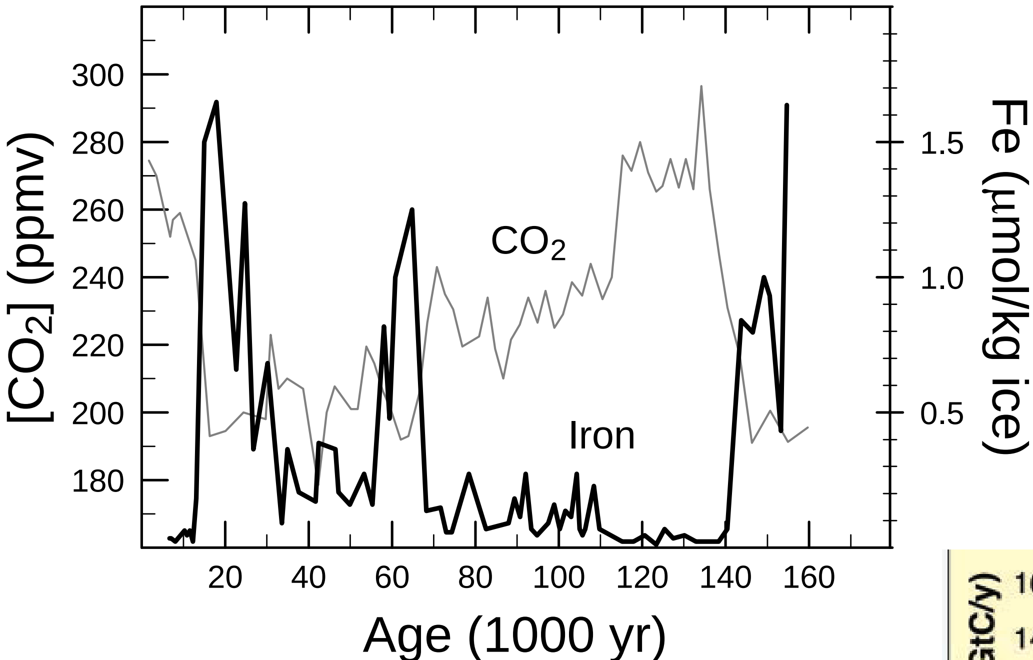
Drought – hydrological cycle

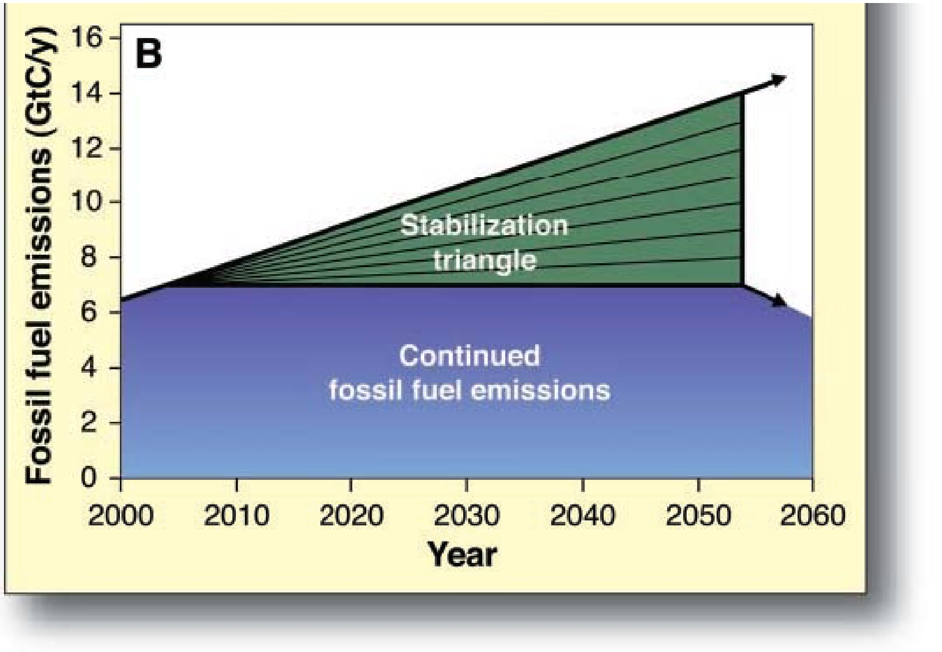
Ozone depletion

Acid rain

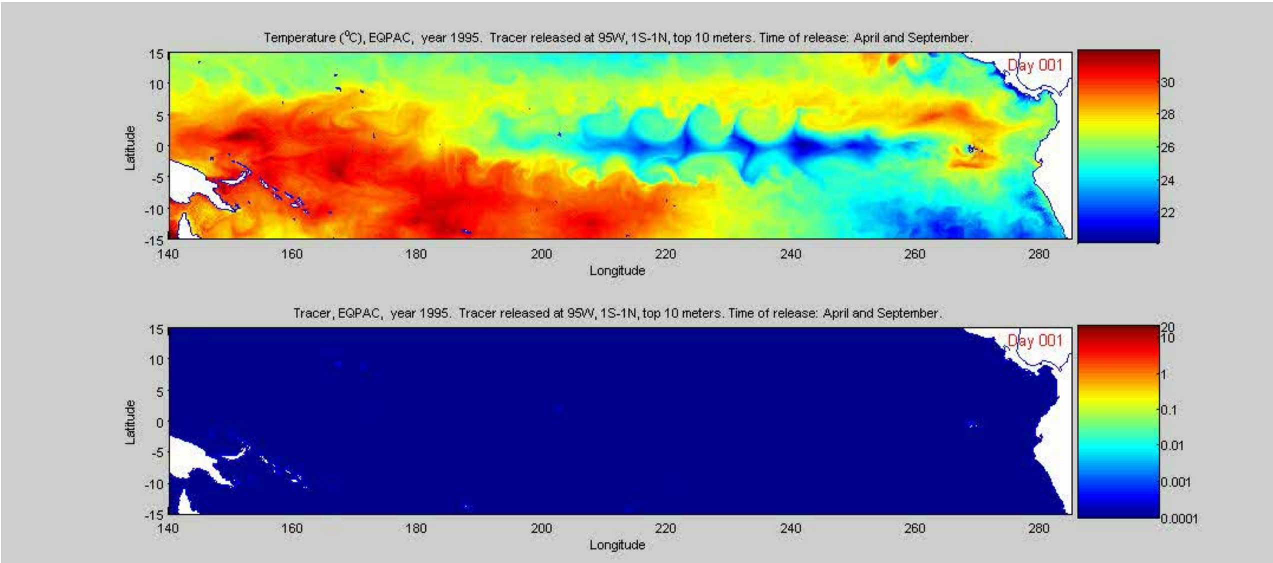
Side-effects were mainly On the Indian sub-continent

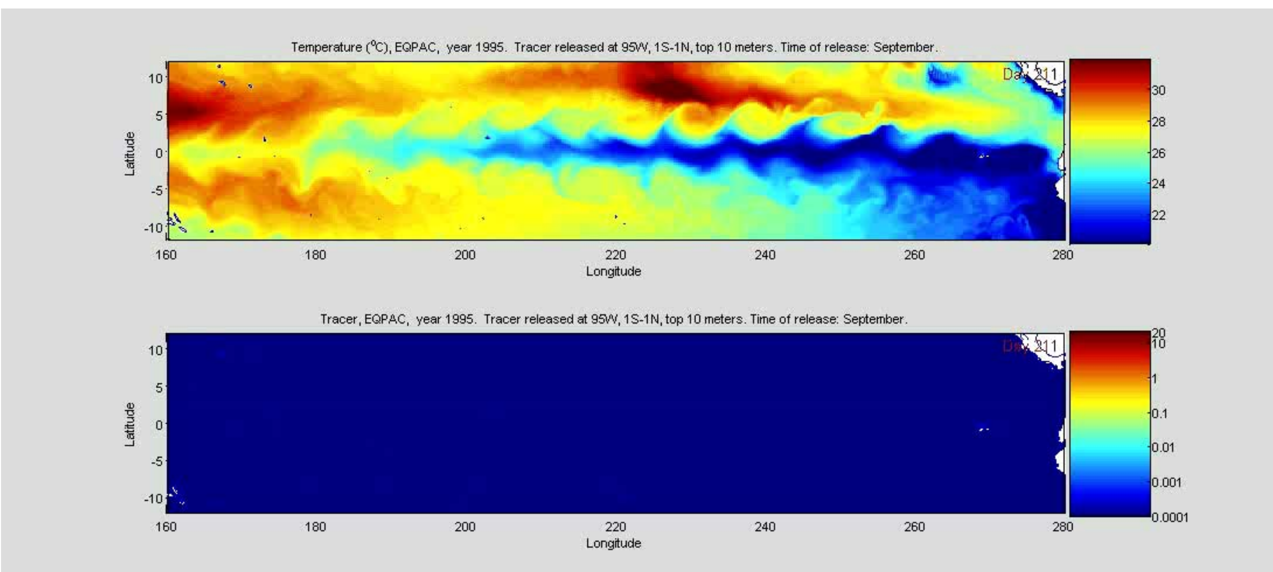
We can assess how rapidly can perturbations alter climate? i.e. what's the mitigation rate?





What happens to perturbations in dynamic environments?





Animation courtesy F. Chai (U. Maine)

What have we learnt to date from proxies, natural perturbations & modelling?

- **Different methods will have very different properties**
- **Mitigation rates**
- **System complexity**
- **Biology > Chemistry > Physics**
- **Safety & side-effects**
- **Residence times**
- **Unknowns……………………………..**

We can compare schemes now

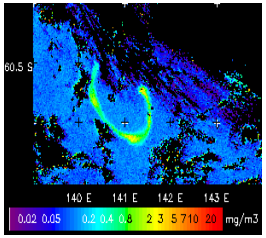
Option	ΔCO_2 (ppm)
Enhance land carbon sink	
Afforestation	−41
Bio-char production	−10
Air capture and storage	−58
Enhance ocean carbon sink	
Phosphorus addition	−6.5
Nitrogen fertilisation	−4.5
Iron fertilisation	−9.0
Enhance upwelling	−0.1
Enhance downwelling	−0.08
Carbonate addition	−0.4

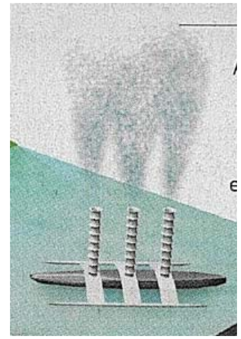
Lenton & Vaughn (2009)

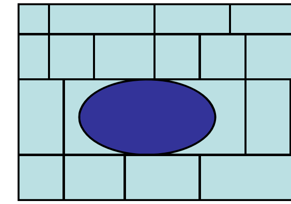
Table 1. Benefits and Risks of Stratospheric Geoengineering[a]

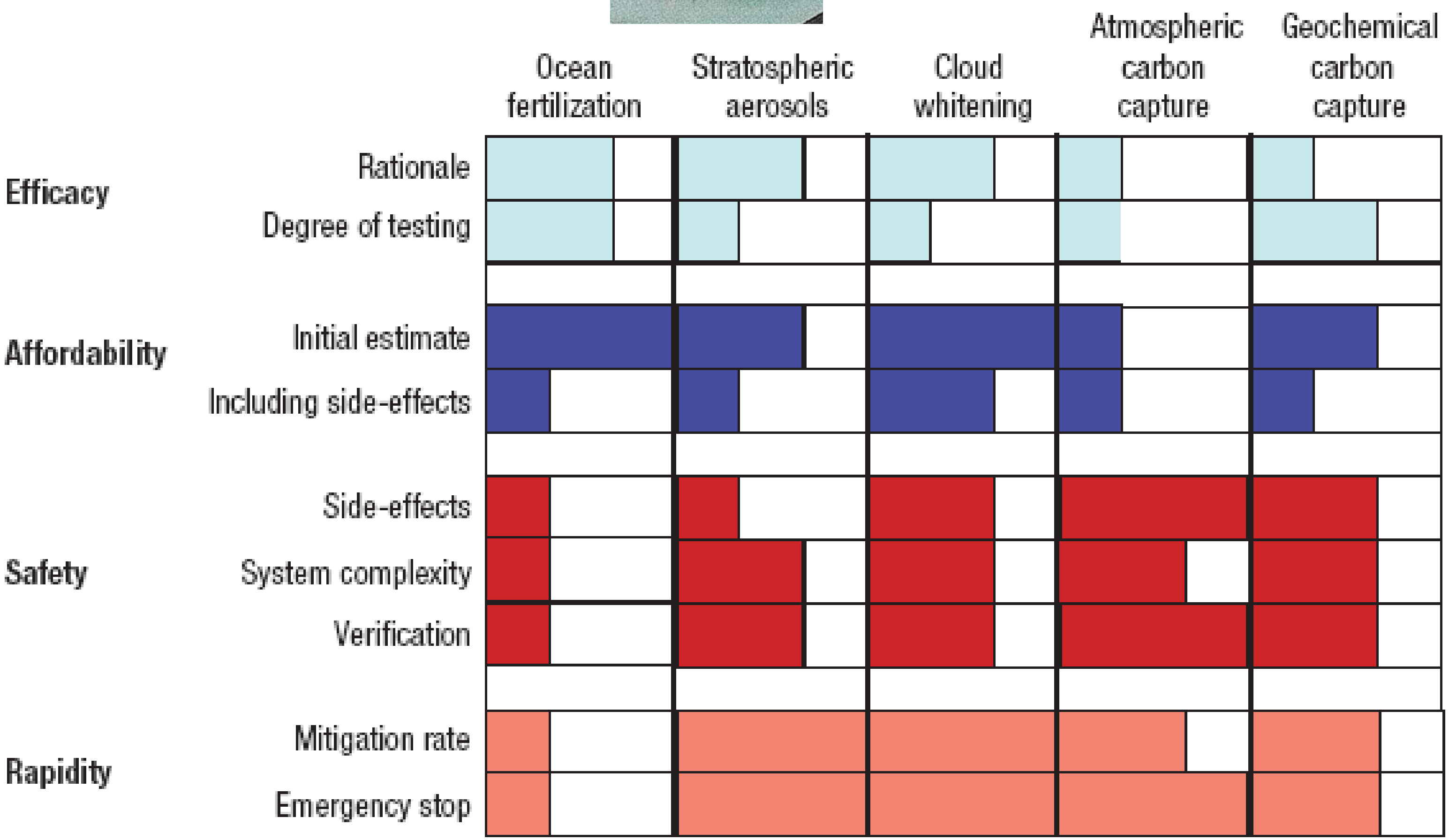
Benefits	Risks
1. Cool planet	1. Drought in Africa and Asia
2. Reduce or reverse sea ice melting	2. Continued ocean acidification from CO_2
3. Reduce or reverse land ice sheet melting	3. Ozone depletion
4. Reduce or reverse sea level rise	4. No more blue skies
5. Increase plant productivity	5. Less solar power
6. Increase terrestrial CO_2 sink	6. Environmental impact of implementation
	7. Rapid warming if stopped
	8. Cannot stop effects quickly
	9. Human error
	10. Unexpected consequences
	11. Commercial control
	12. Military use of technology
	13. Conflicts with current treaties
	14. Whose hand on the thermostat?
	15. Ruin terrestrial optical astronomy
	16. Moral hazard – the prospect of it working would reduce drive for mitigation
	17. Moral authority – do we have the right to do this?

Robock et al. (2009) GRL









Boyd (2008)

Ranking geo-engineering schemes is the next step

Conclusions

- There have been no direct assessments of the effects of different geoengineering methods
- We have to rely on a suite of proxies from other scientific studies in the peer-reviewed public domain
- Together they provide a wealth of indirect information that can be used to compare the pro's and con's of geoengineering methods
- This information permits a preliminary ranking, using a wide range of scientific criteria, to be conducted – the first step towards developing a climate change toolbox.

Conclusions

- There have been no direct assessments of the effects of Geoengineering schemes on ocean ecosystems

- Public-sector funded large scale scientific experiments provide A wealth of indirect information on direct effects on ocean ecosystems

- Iron fertilization results in a wide range of effects – both direct & indirect that influence many aspects of ocean ecosystems

- Results from studies ranging from polar to tropical low iron waters are not uniform but do show many similarities

- In locales were studies have been repeated – SEEDS I &II – the outcome Of iron fertilization was markedly different

- The initial composition of the pelagic ecosystem seems to be influential In determining the outcome of iron fertilization (ratio of grazers to phytoplankton)

Outstanding Issues

- ❑ All data in this presentation are from short term (weeks) relatively Small scale (100 to 1000 km^2) studies

- ❑ The effect of larger scale and/or sustained (years to decadeds) geoengineering schemes on ocean ecosystems is not known

- ❑ Some aspects of ocean ecosystems – such as biodiversity or species succession are poorly understood in most (unperturbed) open ocean waters

- ❑ Hence there is a lack of fundamental underpinning research on some key aspects of ocean ecosystem structure and function that are a Prerequisite for any future research into geoengineering of the ocean

Degree of testing

NATURE|Vol 449|27 September 2007

Ocean pipes could help the Earth to cure itself

SIR — We propose a way to stimulate the Earth's capacity to cure itself, as an emergency treatment for the pathology of global warming.

"The end result of this field experiment was rapid delivery of deep water to the surface followed by catastrophic failure of pump materials under the dynamic stresses of the oceanic environment."

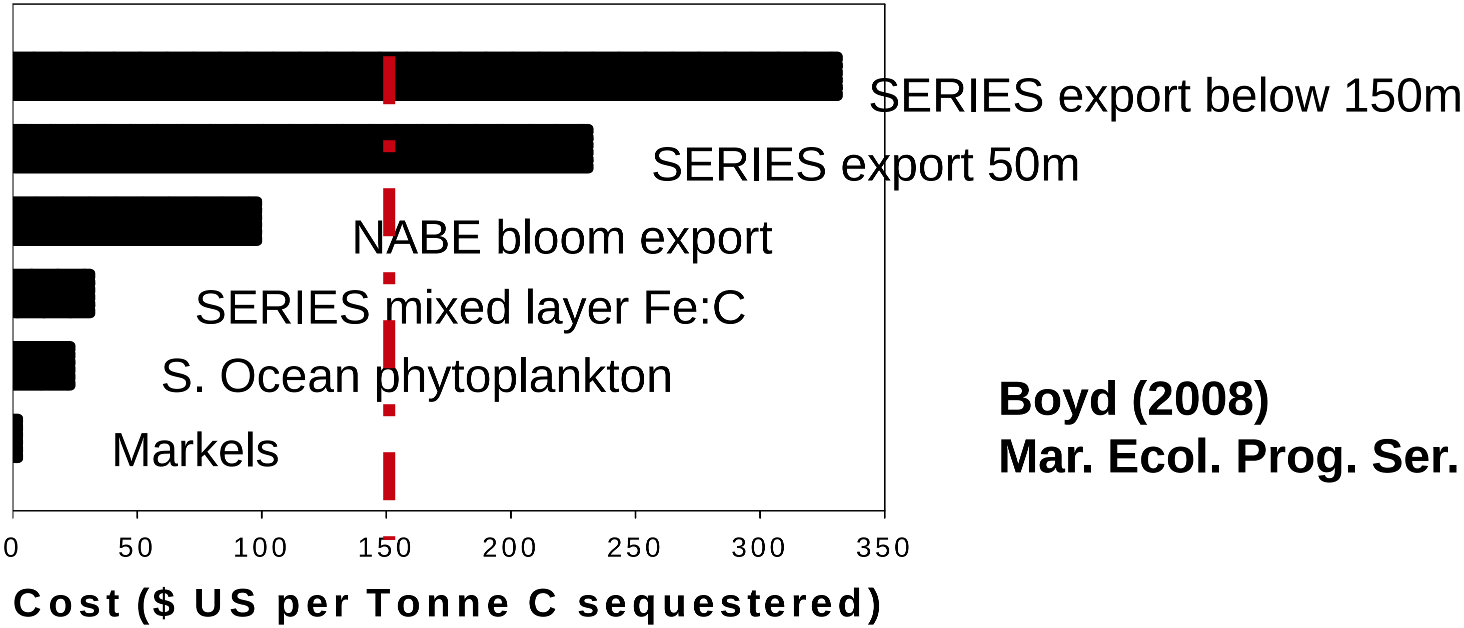
Affordability - initial cost

2 $ a tonne

Initial estimates of costs were simplistic and wildly optimistic

"200 boats, 8.1 M tons of iron, 16 M square miles of HNLC ocean – 8 Gigatons of CO2 each year"

"Dumping Iron", Michael Markels Interview in Wired, November 2000



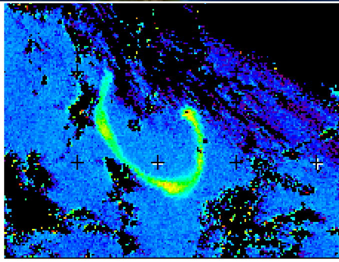
Boyd (2008)
Mar. Ecol. Prog. Ser.

System complexity – varies for land, oceanic, and atmospheric schemes

Biology > Chemistry > Physics

‘Never work with animals or children’

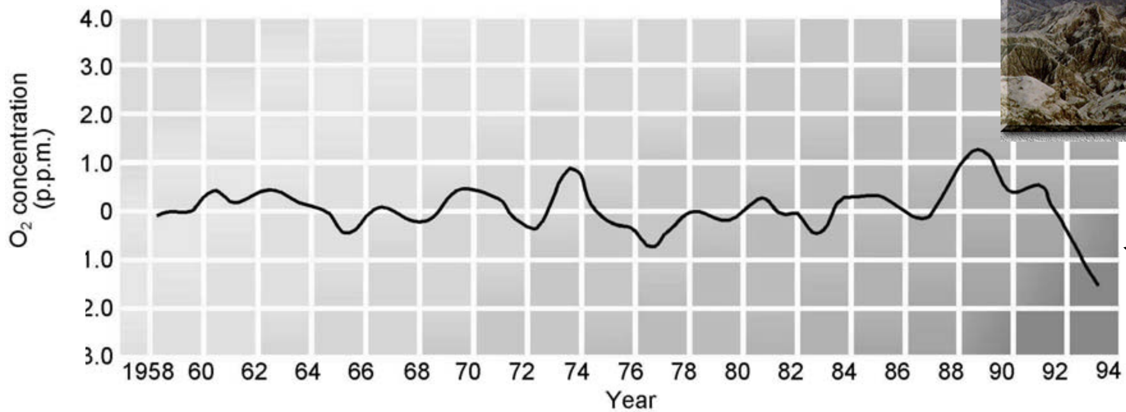
Initial assessment of ocean fertilisation



effective carbon sequestration	**highly uncertain**
cost-effective	**no**
permanent (>100 years)	**site-dependent**
additional	**yes (but how significant?)**
verifiable	**very difficult**
side-effects	**likely; difficult to monitor/attribute**
reversible	**unlikely**
legislation	**developing**

Safety - side-effects

The Earth System is a complex circuit diagram



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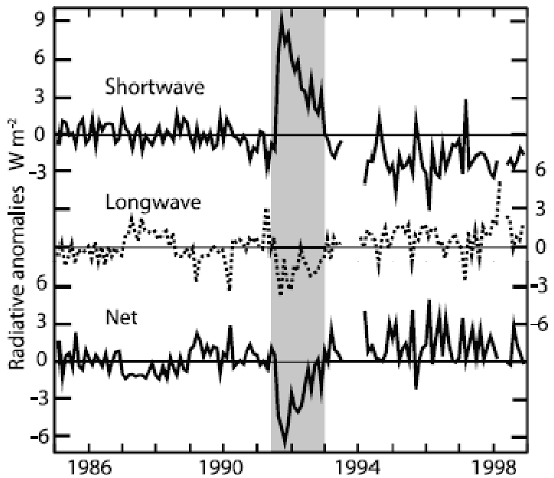
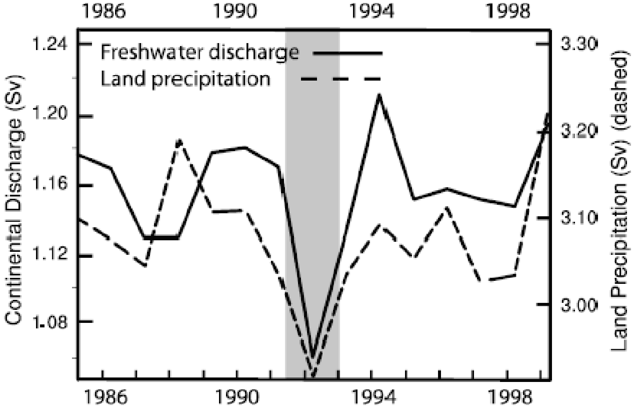
Trenberth & Dai (2007) GRL





Pinatubo also caused:

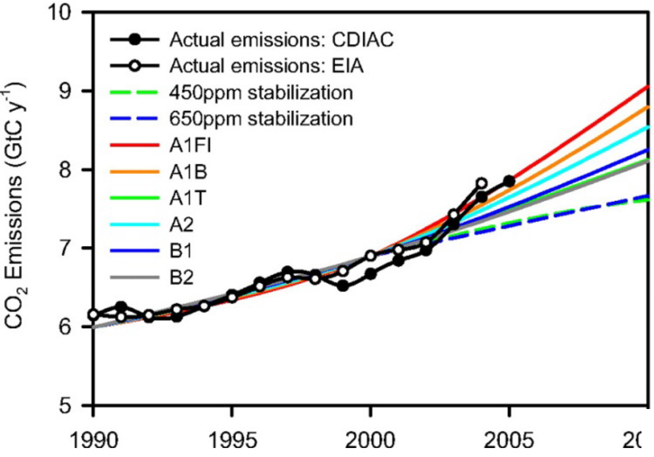
Drought – hydrological cycle

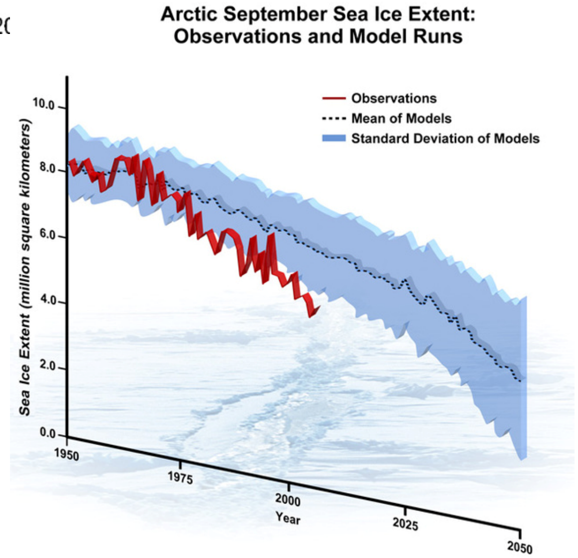
Ozone depletion

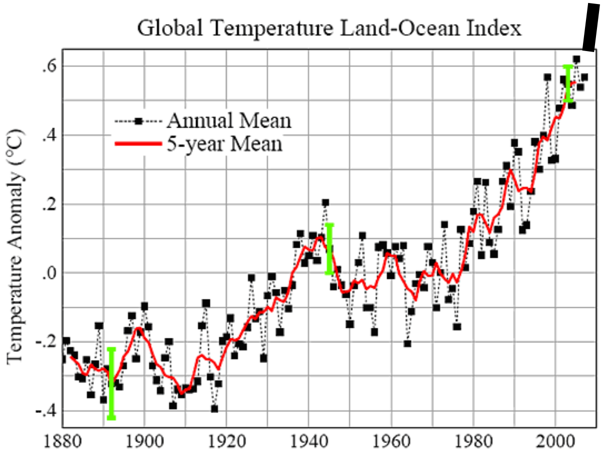
Acid rain

Aerosols into the ocean

The ‘morning after’ scenario







Size of schemes

Option	Area (m^2)	Fraction of Earth f_{Earth}
Increase atmospheric albedo		
Stratospheric aerosols	5.1×10^{14}	1
Cloud albedo – mechanical	8.9×10^{13}	0.175
Cloud albedo – biological	5.1×10^{13}	0.1
Increase surface albedo		
Desert	1.0×10^{13}	0.02
Grassland	3.85×10^{13}	0.075
Cropland	1.4×10^{13}	0.028
Human settlement	3.25×10^{12}	0.0064
Urban areas	2.6×10^{11}	0.00051

Cost of schemes
<u>2 $ a tonne</u>
Initial estimates of costs were simplistic and wildly optimistic

"200 boats, 8.1 M tons of iron, 16 M square miles of HNLC ocean
– 8 Gigatons of CO2 each year"
"Dumping Iron", Michael Markels Interview in Wired, November 2000

COMMUNICATION

“So much for science — the rest is up to politicians and voters.”

Hans Joachim Schellnhuber,
(Potsdam Institute for Climate Impact Research)

Tools & terminology
Uncertainty
Don’t underestimate the public
The best conduits

Direct evidence of geoengineering effects on ocean ecosystems?

Findings of pilot studies & trials

NATURE|Vol 449|27 September 2007

Ocean pipes could help the Earth to cure itself

SIR — We propose a way to stimulate the Earth's capacity to cure itself, as an emergency treatment for the pathology of global warming.

2 h of pumping then the system failed

The results of the 'experiment' were never made public

Results not published, some suggestion of phytoplankton bloom but soon became P-limited