Ocean fertilization: Legislation, ethical considerations and the role of SOLAS

including proposed revised SOLAS statement on ocean fertilization

Report of discussion session at Open Science Conference of Surface Ocean – Lower Atmosphere Study
Cosmo Caixa, Barcelona: 18 November 2009

Introduction

1. The 90 minute discussion session on ocean fertilization was well attended (45-50). It was convened and chaired by Cliff Law (NZ), and the rapporteur was Phil Williamson (UK); together they gave a combined introductory presentation.

2. This paper delivers the three intended outcomes of the session: a report to the SOLAS Scientific Steering Committee (whole document); a potential update of the SOLAS statement on ocean fertilization (Annex 1b); and a summary report for SOLAS News (Annex 2).

3. The existing SOLAS position statement on large-scale ocean fertilization (Annex 1a and online[1]; provided to session participants as background) was published in July 2007 in the context of increasing commercial interest in iron-based marine production enhancements, for carbon sequestration purposes. The SOLAS Scientific Steering Committee was then unconvinced that this approach was viable for climate geoengineering, whilst recognising that uncertainties remained. The statement concludes: "Given our present lack of knowledge, the judgement of the SOLAS SSC is that ocean fertilization will be ineffective and potentially deleterious, and should not be used as a strategy for offsetting CO_2 emissions". The SSC subsequently received a range of responses from scientists to the publication of the statement.

4. The 2009 Open Science Conference included an oral overview by Peter Liss, "SOLAS and the spectre of geoengineering", given at the plenary session preceding the meeting reported here. Whilst the focus of that presentation was ocean fertilization, other proposed geoengineering techniques (including cloud whitening using sprayed seawater, and chemically increasing ocean alkalinity) were also covered.

Recent developments

5. Since 2007 there have been several significant scientific and policy developments that made it timely for SOLAS researchers to discuss ocean fertilization at the programme's 2009 OSC. In particular:

- Debate on the possible benefits (and impacts) of large-scale ocean fertilization is no longer limited to adding iron, nor are potential applications limited to climate geoengineering. The use of macro-nutrients, artificially enhanced upwelling (ocean pipes) and other manipulations have also been proposed, with the aim of improving fisheries in addition to increasing carbon sequestration.
- A joint position statement[2] was released by the Scientific Committee on Oceanic Research (SCOR) and Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) in March 2008, identifying scientific aspects that needed further attention
- The Convention on Biological Diversity (CBD; 9th Conference of Parties, May 2008) stated that ocean fertilization activities should not be carried out until i) there was an adequate scientific basis to justify such actions, and ii) a global, transparent and effective control and regulatory mechanism was in place. Whilst an exception was made for small scale research studies within coastal waters, the CBD's statement resulted in uncertain legal status for scientific studies carried out elsewhere.
- The Lohafex iron fertilization experiment[3] was carried out in the South Atlantic as a joint Indo-German study in February 2009. Although approved by the German government, Lohafex attracted media attention and criticism on the basis that it contravened the CBD moratorium.
- The London Convention and London Protocol (LC/LP; with regulatory remit that covers open ocean "introductions of material and substance of any kind, form or description"), assumed responsibility for international regulation of ocean fertilization activities. Thus the CBD's requirements would be met by a scientific assessment framework and an associated international legal framework, both initially limited to research. Whilst good progress was made at a working group meeting in February 2009 on the scientific framework, the development of the legal framework has been slower[4], with little further development at subsequent meetings in May and October 2009.
- More than 100 papers have been published in this topic area since mid-2007, including 12 linked reviews in MEPS (2008)[5]; other iron-related overviews[6] by Boyd *et al* (2007), Buesseler *et al* (2008), Lampitt *et al* (2008) and Strong *et al* (2009);.and a review of marine urea fertilization by Glibert *et al* (2008)[7]

- The Intergovernmental Oceanographic Commission (IOC) requested a scientific summary for policy makers on ocean fertilization from the SOLAS SSC Chair, Doug Wallace, to be co-authored by other researchers with relevant expertise. A near-final draft of that document (of ~15 pages) was provided to the IOC in October 2009 and also shared with the LC/LP governing bodies. Publication arrangements are currently being discussed.

6. Public awareness of the seriousness of global climate change has increased since 2007, recognising both the need to stabilise atmospheric levels of greenhouse gases, and the difficulty of doing so. Since it is far from certain that 'safe' targets (e.g. 450 ppm CO_2; 2°C global temperature rise) will be met, climate geoengineering is receiving increased attention as a potential fall-back, that might be needed to avert catastrophic temperature increases.

7. Recent reviews of climate geoengineering favouring such a Plan B strategy have included a UK Royal Society report[8] that not only recommended "*Parties to the UNFCCC should make increased efforts towards mitigating and adapting to climate change, and in particular to agreeing to global emissions reductions of at least 50% on 1990 levels by 2050*" but also that "*Further research and development of geoengineering options should be undertaken to investigate whether low risk methods can be made available if it becomes necessary to reduce the rate of warming this century*".

8. The International Geosphere-Biosphere Programme (IGBP, one of SOLAS's sponsors) is planning a Synthesis, Integration and Exploration Topic on 'Geoengineering Facts or Fiction'. This will focus on the key scientific and ethical questions that should be addressed in order to evaluate a range of proposed geoengineering schemes, not just ocean fertilization. Partners are expected to include IHDP (International Human Dimensions Programme on Global Environmental Change) and WCRP (World Climate Research Programme).

Key issues from different perspectives

9. The discussion session recognised that there were at least three different approaches to ocean fertilization, from the perspectives of fundamental science, strategic science and socio-economics. These different approaches involve different priority issues.

10. Taking a *fundamental science approach*, the key need is to gain a quantitative understanding of the linkages between nutrient supply/regeneration and marine ecosystem productivity, particularly in areas of the open ocean where macro-nutrients (nitrate, phosphate and silicate) are high but chlorophyll is low. Additional basic science questions relate to the relationships between past changes in ocean circulation, ocean productivity, and atmospheric dynamics. A series of at-sea fertilization experiments, carried out since the early 1990s, showed that high nutrient – low chlorophyll regions do respond to iron additions, mostly through enhanced primary production (confirming the first part of John Martin's 'iron hypothesis'). Such results have major implications for our understanding of the natural behaviour of the Earth system, and — by establishing the linkage between atmospheric and ocean processes — played a significant role in developing the SOLAS programme.

11. The *strategic science approach* recognises that carbon drawdown (and its potential sequestration) arising from large-scale ocean fertilization might be used for human benefit, as a climate geoengineering tool . Putting aside the question as to whether such action is desirable or undesirable, the main consideration is a pragmatic one: "could it work?". Component issues relate to the feasibility of achieving desired outcomes, e.g.in a framework set by carbon market criteria[9]. Such issues were discussed in the session, primarily relating to iron-based fertilization, and are summarised in Table 1 below.

12. Alternative methods of enhancing ocean productivity (N and/or P additions; enhanced upwelling, via ocean pipes) were not considered in any detail in the session. However, their effectiveness and feasibility have yet to be demonstrated[7,10].

13. The *socio-economic perspective* adds a very different layer of considerations and questions. Whilst some of these are apparently factual (how much will it cost? What is the present legal status?), others are ethical and political, for which answers depend on public perceptions, policy drivers, cultural values and governance structures: "the politics of geoengineering are complex and contested, and the positions taken by scientists and other analysts may interweave policy preferences with technical judgements"[8].

Table 1. Summary assessment of feasibility of iron-based ocean fertilization as a carbon sequestration tool

Generic issues	Ocean fertilization status	Further comments
Effectiveness: what reduction in atmospheric CO_2 could potentially be achieved?	Field experiments have demonstrated short-term CO_2 drawdown, but not longer term sequestration. Model-based estimates of maximum CO_2 global removal are generally <1 Gt C per year,	More recent (and more realistic) model indicate lower CO_2 drawdown than earlier estimates[11]
Permanence: for how long is the carbon removed from the system?	Whilst the return time to the atmosphere of exported C (leaving upper ocean, naturally or Fe-fertilized) is highly site-dependent, relatively little (<10%?) is likely to meet the 'permanence' criterion of >100 years.	Most exported C is returned to the upper ocean/atmosphere on a decadal timescale
Verification: how easy is it to quantify the amount of carbon removed? (and net climatic benefit)	Inherently difficult. Carbon exported from surface waters will be transported laterally over large distances, and may be indistinguishable from that exported from natural blooms	It would seem challenging to limit verification errors to ±20%.
Side-effects: are there any potential impacts affecting usefulness of the approach?	Changes in foodweb structure in surface water will occur, and there may also be oxygen depletion, increased nitrous oxide production[12] and increased acidity in the mid-water column. Complex downstream effects (e.g. 'nutrient robbing') will require a combination of modelling and observations over large space and time-scales[13]	Measurement of side-effects needs to be part of verification[13]
Control/reversibility: can the approach be easily stopped if undesired side-effects occur?	Could be easily halted. Whereas surface waters may revert to initial conditions, recovery of oxygen and nutrient levels in the mid-water column effects may take decades	'Treadmill' effect would develop after initial gains

14. Examples of socio-economic 'should we?' issues (rather than technical 'could we?' ones) include:

- How does the cost-effectiveness of carbon removal by ocean fertilization compare to more direct mitigation techniques, e.g. emission reduction, afforestation or carbon capture/storage at source? This might seem relatively straightforward, to be decided by the operation of carbon markets; however, the cost of achieving reliable verification that X tonnes of carbon has been sequestered for Y years through ocean fertilization could be the most expensive part of the process (with value judgements involved in deciding how comprehensive, and accurate, verification procedures need to be).
- Is ocean fertilization – and all other geoengineering strategies – ethically flawed, not only on the basis of 'moral hazard' (reducing the incentive to reduce emissions) but also because "what makes an action right is not just whether it makes the world better, but also whether those affected agree to having their world made better by others"[14]? .
- Acknowledging that there is need for international approval and regulation of significant activities in this area, how is that to be achieved? i.e. who decides, and by what process, whether large-scale ocean fertilization (whether for research or commercial purposes) should be allowed? On land, no-one would carry out an equivalent large-scale procedure, such as forest fertilization, without seeking necessary permissions and approvals; whilst the open ocean is a global resource (and over-exploited in many other regards, e.g. fishing), that common ownership increases, rather than decreases, the need for a formal and well-accepted approval process. Is the current mix of international bodies (CBD, LC/LP and IOC) appropriate, or should others (e.g. UN Convention on the Law of the Sea and UN Framework Convention on Climate Change; the latter with carbon credit role) be involved?

Role of SOLAS researchers in decision-making

15. The discussion session recognised that SOLAS researchers are able to contribute substantively to the above debates, and hence societal decision-making, in several ways and at different levels. Clearly, the community's main role is as knowledge producers, discovering and disseminating unbiased factual information through fundamental and strategic science. This must be done honestly, openly and independently, subject to peer review and following the highest scientific standards.

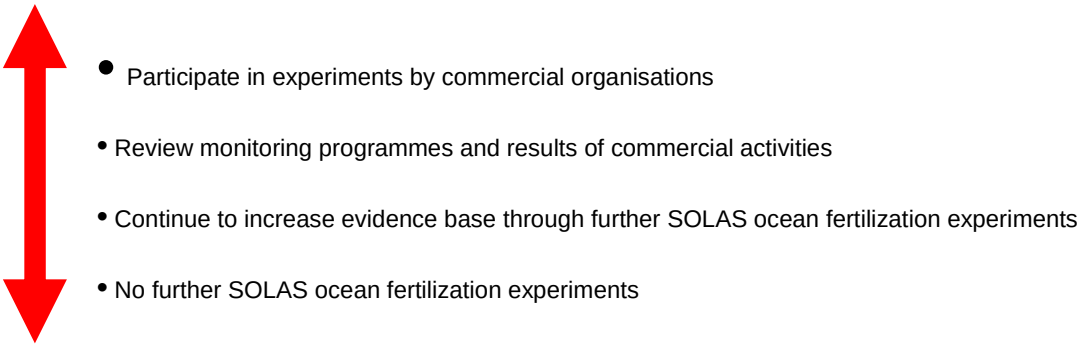
16. A second role, now being given increasing importance by many national funding bodies, is through knowledge exchange (KE) activities – actively delivering outputs to either the public or private sector. Thus the individual or collective advice of SOLAS researchers can help inform national governments, international bodies, commercial companies, the media or the general public, to assist interpretation of the complex and sometimes conflicting scientific literature. Examples of such 'evidence-to-policy' and

'public understanding' work include involvement in international regulatory discussions (e.g. by the LC/LP), the preparation of assessment reviews (e.g. for IOC), public lectures, and press interviews. Whilst engagement in such KE activities is generally non-controversial, it is not entirely risk-free: there may be 'hidden agendas' and mis-representation can occur.

17. An analogy made in support of KE involvement was that SOLAS scientists are the "car mechanics of the ocean", having the expertise to diagnose problems and recommend appropriate responses. Our expertise may be incomplete; nevertheless, since SOLAS research is almost entirely paid for by governments, and hence public taxation, there is a responsibility to use the knowledge we do have (whilst seeking more) for wider public benefit.

18. The contrasting position is that "scientists should stick to science", since any involvement with policy/business domains necessarily involves a conflict of interests, compromising scientific independence. Nevertheless, commercial organisations that are interested in large-scale ocean fertilization are already interacting with scientists, with one organisation having developed a Code of Conduct that specifically addresses scientific-commercial interactions. Interaction with such companies (and the inherent direction of future iron experiments) may cause some degree of polarization of the scientific community. Two examples were raised to support a more cautionary approach: 'scientific' whaling, that is widely considered a misnomer; and work with pharmaceutical companies, that may not necessarily result in the cheapest treatments or might involve other ethical problems e.g. re drug trials.

19. The range of potential future SOLAS research directions relating to ocean fertilisation were briefly considered during the discussion, as summarised in the figure below.



20. It is necessarily an individual choice of each researcher where to focus his or her effort along the spectrum of pure to applied science. The third role of SOLAS scientists in geoengineering decision-making is hence at the individual level, as well-informed citizens of the world. Thus personal value judgements, based on direct evidence assessments rather than prejudices or vested interests, are ultimately of over-riding importance — whilst respecting that others may hold different views.

21. An informal 'straw poll' was taken in this context, to assess the mood of the meeting based on individual opinions. The question asked was "Do you think ocean fertilization has potential for geoengineering?" with three response options initially give. These options, and the split between them, were as follows, based on a show of hands:

"No. Definitely not, don't even think about it"	8	(17%)
"Maybe. Keep options open"	35	(76%)
"Yes. Worth serious attention (as Plan B)"	0	(0%)
[Abstentions/don't know	~3	(7%)]

22. A subsequent poll was taken without the 'maybe: keep options open' option. The response to the same question "Do you think ocean fertilization has potential for geoengineering?" was then:

No	42	(91%)
Yes	1	(2%)
[Abstentions/don't know	~3	(7%)]

23. The lack of support for ocean fertilization as a means to combat climate change — even its *potential* application, Question 2 — might have been due to the fact that no proponent of geoengineering (e.g. a representative of Climos, the Ocean Nourishment Corporation, or research groups advocating a Plan B approach) had given a presentation to the session. However, most SOLAS researchers with interests in this

area, and hence session participants, could be expected to be reasonably familiar with relevant literature on both sides of this debate, that has had a high profile in recent years.

24. Further discussions in the remainder of the session confirmed that that concerns were more pragmatic than ethical. In particular, the non-permanence of the carbon 'sequestration'; the uncertainties concerning side effects (production of other greenhouse gases); the verification problems; and the mismatch of scales between potential additional ocean carbon uptake and the current rate of anthropogenic carbon emissions were major reasons why ocean fertilization was rejected as the solution, or even part of the solution, to global climate change.

Update of the SOLAS position statement

25. As indicated above, the consensus of the discussion session was consistent with the 2007 SOLAS SSC position statement (Annex 1a), that effectively rejected ocean fertilization as a viable geoengineering tool.

26. Whilst there were no major objections to the 2007 SOLAS statement in the discussion session, it may nevertheless benefit from some clarification and updating, to take account of developments over the past two years and to improve aspects of the wording. Semantic concerns relate to:

- The ambiguity of 'significantly' in the context of potential increased carbon transfers (2nd sentence)
- The logical inconsistency of undertaking 'verification' before large-scale fertilization is considered (penultimate sentence)
- The apparent contradiction between current lack of knowledge and the apparently firm conclusion that ocean fertilization would be ineffective (final sentence).

27. A suggested revised text is given in Annex 1b below, for the SOLAS SSC's consideration.

Notes and references

1. Online at www.solas-int.org/aboutsolas/organisationandstructure/sciencesteercomm/sscmins/position.statement.pdf. This statement has also been adopted by the German SOPRAN programme.
2. Position of SCOR and GESAMP on deliberate nutrient additions to the ocean; online at www.scor-int.org/SCOR-GESAMP.pdf
3. Information on the LOHAFEX cruise at www.nio.org/projects/narvekar/narvekar_NWAP2.jsp
4. LC/LP 2009 technical working group report at www.imo.org/includes/blastDataOnly.asp/data_id%3D25080/5.pdf; legal working group report at /www.imo.org/includes/blastDataOnly.asp/data_id%3D25078/5.pdf
5. Theme section of *Marine Ecology Progress Series* (2008); vol 364, 213-309. Some individual papers are also cited below.
6. Boyd PW and 22 others (2007) Mesoscale iron enrichment experiments 1993-2005: synthesis and future directions. *Science* 315, 5812, 612-7; Buesseler KO and 15 others (2008) Ocean iron fertilization – moving forward in a sea of uncertainty. *Science* 319, 162; Lampitt RS and 11 others (2008) Ocean fertilization: a potential means of geoengineering? *Phil Trans Roy Soc A,* 366 (1882) 3919-45; Strong AL, JJ Cullen & SW Chisholm (2009) Ocean fertilization. Science, policy and commerce. *Oceanography* 22, 236-61.
7. Glibert PM and 56 others (2008) Ocean urea fertilization for carbon credits poses high ecological risks. *Mar Poll Bull* 56, 1049-56.
8. Royal Society (2009) *Geoengineering the climate: science, governance and uncertainty*. RS Policy Document 10/09.
9. Leinen M (2008) Building relationships between scientists and business in ocean iron fertilization. *Marine Ecology Progress Series*, 364, 251-6.
10. Yool A, JG Shepherd, HL Bryden & A Oschlies (2009) Low efficiency of nutrient translocation for enhancing oceanic uptake of carbon dioxide. *J Geophysical Research - Oceans,* 114, doi C08009.
11. Denman K (2008) Climate change, ocean processes and ocean iron fertilization. *Marine Ecology Progress Series*, 364, 219-25.
12. Law CS (2008) Predicting and monitoring the effects of large-scale ocean iron fertilization on marine trace gas emissions. *Marine Ecology Progress Series*, 364, 283-8.
13. Cullen JJ & Boyd PW (2008) Predicting and verifying the intended and unintended consequences of large-scale ocean iron fertilization. *Marine Ecology Progress Series*, 364, 295-301.
14. Hale B "You say solution, I say pollution" at www.scienceprogress.org/2009/08/ocean-fertilization-ethics. Also Hale B & L Dilling (2010) Carbon sequestration, ocean fertilization,and the problem of permissible pollution. *Science, Technology & Human Values,* in press

Annex 1 SOLAS position statement

a) 2007 SOLAS SSC position statement on large-scale ocean fertilization

"Large-scale fertilisation of the ocean is being actively promoted by various commercial organisations as a strategy to reduce atmospheric CO_2 levels. However the current scientific evidence indicates that this will not significantly increase carbon transfer into the deep ocean or lower atmospheric CO_2. Furthermore there may be negative impacts of iron fertilization including dissolved oxygen depletion, altered trace gas emissions that affect climate and air quality, changes in biodiversity, and decreased productivity in other oceanic regions. It is then critical and essential that robust and independent scientific verification is undertaken before large-scale fertilisation is considered. Given our present lack of knowledge, the judgement of the SOLAS SSC is that ocean fertilisation will be ineffective and potentially deleterious, and should not be used as a strategy for offsetting CO_2 emissions."

b) Potential update on the SOLAS SSC position statement on large-scale ocean fertilization

"Policy and public interest in potential geoengineering solutions to climate change has increased since the 2007 position statement by the Scientific Steering Committee of the international Surface Ocean – Lower Atmosphere Study (SOLAS SSC). In light of the scientific developments in this area and further discussion with the SOLAS research community, the SOLAS SSC has re-visited this issue and

i) *notes* the work of international bodies in developing technical and legal frameworks for the regulation of large-scale ocean fertilization activities

ii) *welcomes* the proposed technical framework for ocean fertilization experiments developed by the London Convention/ London Protocol, and *encourages* the complementary development of an internationally-agreed legal framework that would not unnecessarily constrain legitimate scientific research

iii) *notes* that global models now indicate that maximum carbon removal through continuous global iron fertilization is around 5-10% of emissions

iv) *recognises* that there are still major uncertainties in the feasibility of ocean fertilization for geoengineering purposes, particularly with regard to the length of time that carbon dioxide is removed from the atmosphere and how this will be robustly verified, and in the scale and significance of side-effects, such as the production of other climatically-active gases, and impacts on food web dynamics and ecosystem structure

v) *considers* that quantitative assessment of the effectiveness of ocean fertilization, through observation and modeling over large space and time scales, is essential before ocean fertilization could be recognized for carbon trading purposes

vi) *concludes* that the SSC's overall assessment remains (as in 2007) that large-scale ocean fertilization is unlikely to be a viable strategy for achieving the reduction in atmospheric greenhouse gases."

Annex 2 Summary report for SOLAS News

Thumbs down for ocean fertilization as a geoengineering strategy

Could adding iron, or any other means of stimulating ocean productivity, provide an effective means of counteracting global warming? And if it could, should we do it? Those were the topics for the "Ocean fertilization" discussion session, which covered not only the current scientific understanding but also considered legislative and ethical considerations.

The starting point was recent legal developments (by the Convention on Biological Diversity and the London Convention), that limit open ocean research and restrict commercial activities in this area. Whilst an international scientific framework has been drafted to allow research to continue (subject to an impact assessment procedure), the international approval process has still to be resolved.

The role of the SOLAS community in policy development was considered in some detail, recognizing the key contributions of SOLAS researchers in knowledge production and assessment. A range of future approaches was discussed, from collaboration with commercial organizations on geoengineering trials to no further iron addition experiments. The majority of session participants did not consider that ocean fertilization had potential for geoengineering, on the basis of three perceived flaws: that carbon 'sequestration' was mostly temporary, not permanent; production of other trace gases may negate some benefits of CO_2 drawdown; and quantification and verification of carbon removal from the atmosphere would be complex, costly and uncertain.

Overall, these views closely matched the 2007 SOLAS position statement on large-scale ocean fertilization. A more detailed report of the discussion is available on the SOLAS website. That report includes a proposed update of the SOLAS position statement, taking into account recent developments.

Cliff Law (Convenor) and Phil Williamson (Rapporteur)

[257 words]