PROCEEDINGS OF THE 2015 SCIENCE DAY SYMPOSIUM ON

MARINE GEOENGINEERING

HELD ON 23 APRIL 2015 AT IMO HEADQUARTERS
LONDON, UNITED KINGDOM

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LONDON CONVENTION AND PROTOCOL

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INTERNATIONAL MARITIME ORGANIZATION

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Executive Summary

The 2015 Science Day Symposium on Marine Geoengineering was held on Thursday, 23 April 2015, at the Headquarters of the International Maritime Organization (IMO), London, United Kingdom and attended by approximately 100 participants. The symposium was hosted and organized by the Office for the London Convention/Protocol and Ocean Affairs. The Science Day programme is at annex 1.

The invited participants represented the scientific community, marine geoengineering experts, policy makers, IMO Member States' delegations and permanent representations in London. The aim of the Symposium was to create a forum where key stakeholders broaden their shared scientific understanding on the topic in a more informal setting. A list of speakers is at annex 2.

Group photograph of speakers and several participants

Background

The International Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter, 1972 (London Convention) and its 1996 Protocol (London Protocol) are two separate but related treaties administered by the IMO.

Article I of the London Convention and the objective (Article 2) of the London Protocol are similar and aim to:

> "…….protect and preserve the marine environment from all sources of pollution and take effective measures, according to their scientific, technical and economic capabilities, to prevent, reduce and where practicable eliminate pollution caused by dumping or incineration at sea of wastes or other matter."

The treaties therefore govern dumping activities *world-wide*, but always from the perspective of protection of the marine environment from all sources of pollution[1].

The London Protocol was adopted in 1996 to modernize the London Convention after more than 20 years of practical experience. The London Protocol, considered to be a more stringent agreement for the protection of the marine environment, entered into force on 24 March 2006.

[1] Recent developments and related information can also be obtained at the London Convention and Protocol website: http://londonprotocol.imo.org.

The Protocol will supersede the Convention as between Contracting Parties to this Protocol which are also Parties to the Convention. The intention is for the London Protocol to eventually replace the London Convention. While States are transitioning from the London Convention to the London Protocol, the two treaties will operate in parallel with joint meetings of the Parties. The most recent list of Contracting Parties to the London Convention and the London Protocol may be found by accessing the IMO website[2].

Marine Geoengineering under the London Protocol

In June 2007, the Scientific Groups under the London Convention and Protocol considered several submissions relating to large scale iron fertilization of the oceans to sequester CO_2. This practice is aimed at drawing down an additional amount of surplus CO_2 from the atmosphere in the oceans for sequestration purposes.

In November 2007, the Contracting Parties endorsed the view that the scope of work of the London Convention and Protocol included ocean fertilization, as well as iron fertilization, and that these agreements were competent to address this issue due to their general objective to protect and preserve the marine environment from all sources. Recognizing that it was within the purview of each State to consider proposals on a case-by-case basis in accordance with the London Convention and Protocol Parties, urged States to use the utmost caution when considering proposals for large-scale ocean fertilization operations.

In this regard the governing bodies of the London Convention and Protocol also endorsed the ‘Statement of Concern’ regarding iron fertilization of the oceans to sequester CO_2, which had been developed by the Scientific Groups (LC-LP.1/Circ.14)[3].

In October 2008 the Contracting Parties developed and adopted a (non-binding) resolution on the regulation of ocean fertilization (LC-LP.1(2008)). By this resolution Parties declared, inter alia, that, “given the present state of knowledge, ocean fertilization activities other than legitimate scientific research should not be allowed”. In addition, it was agreed to further consider a potential legally binding resolution or an amendment to the London Protocol on ocean fertilization in the future. Furthermore, the governing bodies commenced the preparation of a document, for the information of all Contracting Parties, summarizing the current state of knowledge on ocean fertilization, relevant to assessing impacts on the marine environment, taking into account the work done on this issue in other fora.

In 2010 the Contracting Parties adopted resolution LC-LP.2(2010) on the ‘Assessment Framework for Scientific Research Involving Ocean Fertilization’, the development of which was required under the 2008 resolution prohibiting ocean fertilization activities for purposes other than legitimate scientific research. This Assessment Framework guides Parties on how to assess proposals they receive for ocean fertilization research and provides criteria for an initial assessment of such proposals, including detailed steps for completion of an environmental assessment, which encompasses risk management and monitoring.

In 2013, the Contracting Parties to the London Protocol adopted resolution LP.4(8) on the ‘Amendment to the London Protocol to regulate the placement of matter for ocean fertilization and other marine geoengineering activities’. The amendment adds a new article 6bis which states that “Contracting Parties shall not allow the placement of matter into the sea from vessels, aircraft, platforms or other man-made structures at sea for marine geoengineering

[2] http://www.imo.org/About/Conventions/StatusOfConventions/Pages/Default.aspx.

[3] Accessible via self-registering website: https://docs.imo.org/Category.aspx?cid=624.

activities listed in Annex 4, unless the listing provides that the activity or the sub-category of an activity may be authorized under a permit".

The London Protocol defines marine geoengineering as the "deliberate intervention in the marine environment to manipulate natural processes, including to counteract anthropogenic climate change and/or its impacts, and that has the potential to result in deleterious effects, especially where those effects may be widespread, long-lasting or severe".

Marine geoengineering under the London Protocol does not include: direct harvesting of marine organisms; conventional aquaculture or mariculture; the creation of artificial reefs; use of dispersants in oil spill response; or the production of energy from the wind, currents, waves, tides, or ocean thermal energy conversion; deep sea mining; or conventional marine observation and sampling methods.

The new Annex 4 on "Marine geoengineering" lists "Ocean fertilization", defined as "any activity undertaken by humans with the principal intention of stimulating primary productivity in the oceans. Note that ocean fertilization does not include conventional aquaculture, or mariculture, or the creation of artificial reefs. The Annex provides that all ocean fertilization activities other than those referred to above shall not be permitted. An ocean fertilization activity may only be considered for a permit if it is assessed as constituting legitimate scientific research taking into account any specific placement assessment framework.

A new Annex 5 adds the new Assessment Framework for matter that may be considered for placement under Annex 4. The Assessment Framework provides that Contracting Parties should consider any advice on proposals for activities listed from independent international experts or an independent international advisory group of experts.

In 2014, the Contracting Parties to the London Protocol approved the 'Description of arrangements for a roster of experts on marine geoengineering in the consultation process (with regard to paragraph 12 of Annex 5 to the London Protocol)'. For the time being, the roster, which is administered by the IMO Secretariat, will only include experts on ocean fertilization because that is the only marine geoengineering activity currently listed under Annex 4 to the London Protocol.

To date, no Parties have accepted the amendment. Resolution LP.4(8), which includes the full text of the Assessment Framework, was circulated as LC-LP.1/Circ.61[4]. The 'Description of arrangements for a roster of experts on marine geoengineering in the consultation process (with regard to paragraph 12 of Annex 5 to the London Protocol)' was issued as LC-LP.1/Circ.66[5].

A wide variety of techniques have been proposed in the field which involve either adding substances to the ocean or placing structures into the ocean, primarily for climate mitigation purposes but also for the purpose of enhancing fisheries. These techniques are often little more than concepts but most of them involve large scale interventions in the ocean with the potential for significant impacts on the marine environment. In addition, many of these activities would be likely to take place on the high seas outside areas of national jurisdiction and therefore raise international concerns. While a number of reviews of geoengineering per se have considered a certain number of marine geoengineering techniques, mainly for their efficacy, none have reviewed a wide range of marine geoengineering techniques for their marine environmental impacts. For further reading see annex 3 of this document.

[4] Accessible via self-registering website: https://docs.imo.org/Category.aspx?cid=624.
[5] Idem.

Scientific Groups' Science Day

Science Day under the Scientific Groups' meetings of the London Convention and Protocol is hosted annually and provides a forum for scientists to share views on designated topics related to the remit of London the Convention and Protocol. Contracting States and interested observers may use it as a resource to develop their knowledge and make informed decisions.

During the November 2014 joint session of the governing bodies of the London Convention and Protocol, it was decided that a one-day symposium on Marine Geoengineering be organized as part of Science Day during the 2015 joint session of the Scientific Groups, to further increase the visibility and understanding of marine geoengineering issues.

The First Vice-Chairman of the Scientific Groups, Ms. Linda Porebski (Canada), moderated the 2015 Science Day which was held on Thursday, 23 April 2015. The session included presentations, panel-discussions, and poster sessions. Ample time was allocated for participants to mingle and continue informal discussions during the breaks. Invitations to the session were extended beyond the Scientific Groups to interested experts and proponents who provided a diverse audience and varied questions for speakers and panellists.

Moderator Ms. Linda Porebski leads the discussion

The Scientific Groups were offered presentations from a selected list of regulators, policy and governance experts, scientists, and from several prospective marine geoengineering proponents from Australia, Canada, Germany, the Netherlands, and the United Kingdom. In general, the day was organized to provide an overview of the different types of marine geoengineering, and speakers explored the practical, environmental, and socioeconomic aspects of developing and considering the eventual deployment of these techniques.

The presentations were followed by two panel discussions on the following topics:

.1 assessment, monitoring, impacts and benefits – what are the biggest lessons learned thus far?

.2 what will be most important to success in the next decade or two on marine geoengineering?

Speakers at the Symposium

Developments since the Science Day

Recently, a new GESAMP[6] working group on marine geoengineering has been established under the lead of IMO and with the support of IOC of UNESCO and WMO. The objectives of the working group is to better understand the potential impacts of marine geoengineering approaches on the marine environment. One of the main objectives is to provide information to Parties considering the regulation of marine geoengineering activities under the newly amended London Protocol.

The first meeting of the working group is scheduled to be held from 23 to 25 May, 2016, at IMO Headquarters in London, United Kingdom. A report of this meeting will be posted on the GESAMP website (http://www.gesamp.org/work-programme/workgroups/working-group-41).

[6] Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) is an advisory body that advises the United Nations (UN) system on the scientific aspects of marine environmental protection (www.gesamp.org).

Summaries of presentations[7]

1 Brief summary of marine geoengineering techniques – Dr. Chris Vivian[8]

Dr. Vivian described an array of marine geoengineering techniques that could be described as either ‘Solar Radiation Management’ techniques, or ‘Carbon Dioxide Removal’ techniques. He also described how these techniques might intersect with the remit of the London Convention and Protocol whenever they involved the deposit of wastes or structures on or into the marine environment. Because of the uncertainties about both the techniques themselves as well as their effects, it would often not be clear whether such deposits would be dumping or placement under the London Protocol. The presentation touched on the marine geoengineering techniques that had been proposed on or in the ocean (e.g. ocean fertilization, use of marine macroalgae for carbon sequestration, deposition of crop wastes on the seabed, increasing ocean albedo, enhancing ocean alkalinity, partial or complete damming of ocean straits, etc.), and other types of geoengineering that could have implications for the world’s oceans (e.g. marine cloud brightening, ocean thermal energy conversion, deep water source cooling, and weakening hurricanes). It was noted that many proposed schemes would involve placing substances/wastes or structures in the ocean for purposes other than climate change mitigation, and that these schemes could have effects similar in scale and severity to those that could result from climate geoengineering.

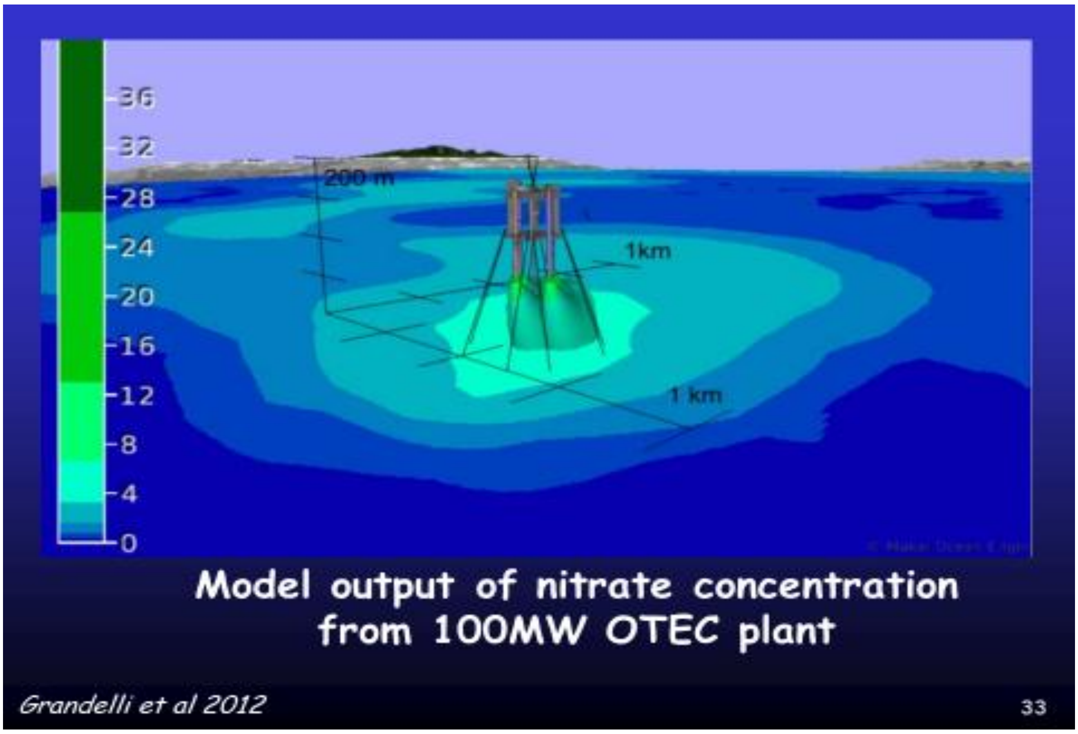
View of the audience

[7] All presentations are available at: http://www.imo.org/en/OurWork/Environment/LCLP/EmergingIssues/geoengineering/Documents/ScienceDay2015ppts.zip

[8] Centre for Environment Fisheries and Aquaculture Science (Cefas), United Kingdom

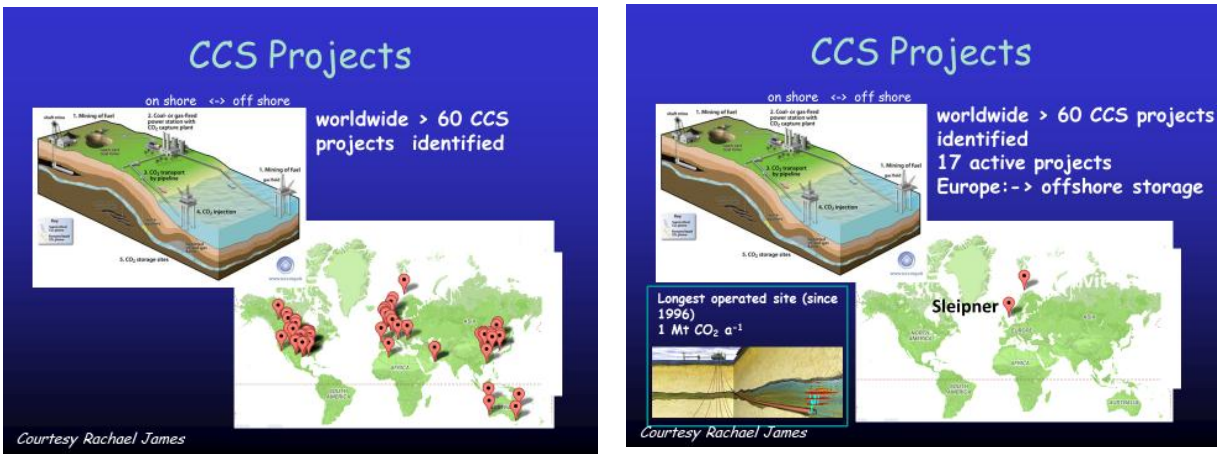
2 Ocean Carbon Capture and Storage (OCCS): The concept and its implications as a geoengineering option – Dr. Richard Lampitt[9]

Dr. Lampitt provided a high-level overview of the ways in which natural ocean processes remove carbon from the atmosphere: namely, via the biological carbon pump and the solubility pump. He then assessed the likely efficacy (i.e. will it work?) and other implications (i.e. is it safe / legal / ethical?) of ocean carbon capture and storage (OCCS) and ocean thermal energy conversion (OTEC).



He concluded that a combination of these techniques could enhance the oceanic uptake of atmospheric carbon, but that significant engineering, modelling, and both lab and field experimentation would first be required. Furthermore, he noted that environmental assessment would be needed to evaluate potential unintended consequences of these interventions (e.g. the effects on phytoplankton responses and the biological carbon pump, triggering of harmful algal blooms, etc.), and that issues of verification of efficacy and commercial feasibility remain to be addressed. He also noted that there were uncertainties regarding the movement of water once discharged at depth, and stressed that OTEC would generate substantial quantities of CO_2 from seawater that would need to be addressed in some way.

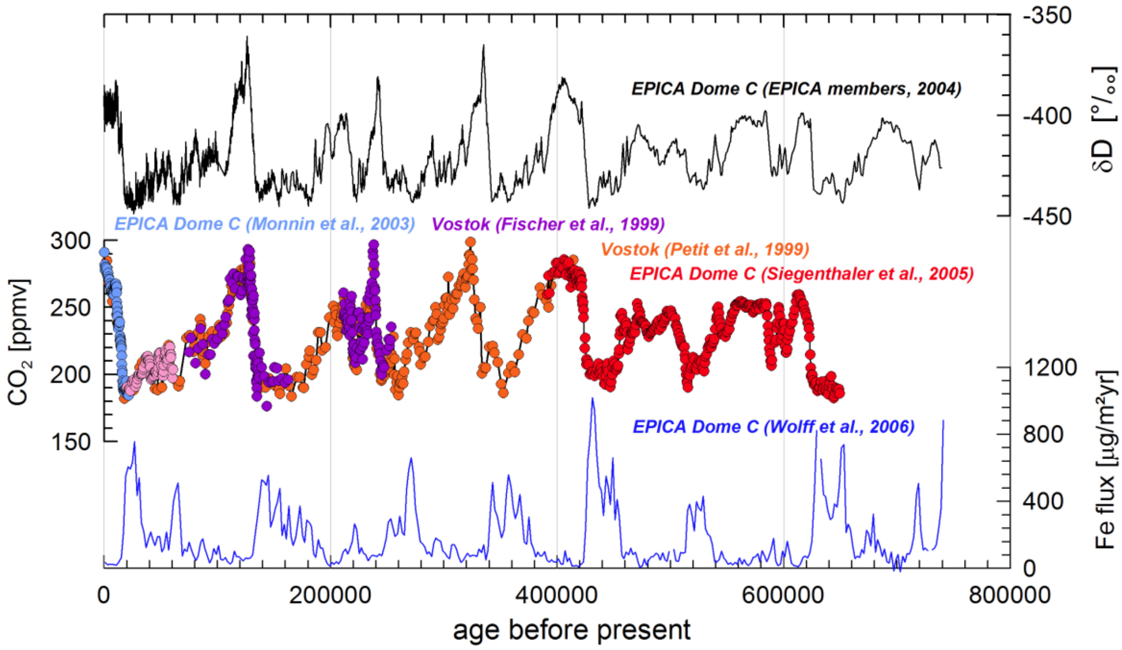
[9] National Oceanography Centre, United Kingdom



An indicative map of CCS Projects

3 Ocean iron fertilization: overview and perspectives – Dr. Christine Klaas[10]

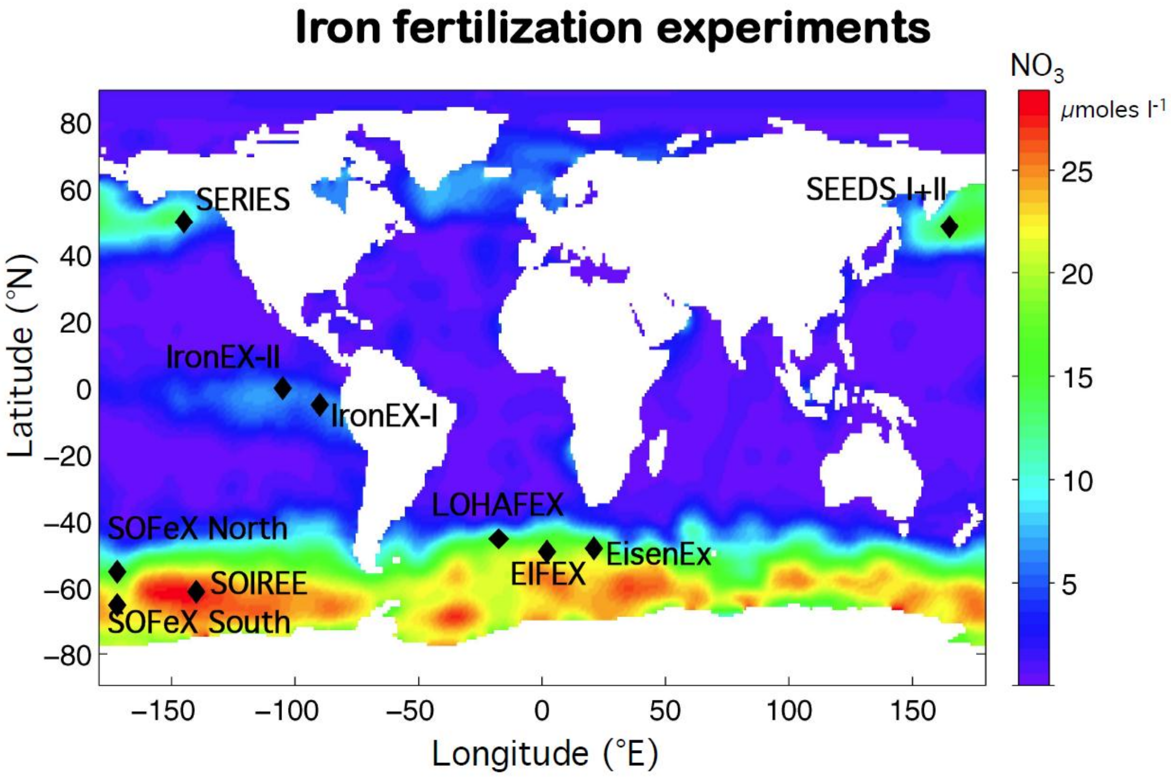
In this presentation, Dr. Klaas explained the science behind ocean fertilization and the reasons why iron is a nutrient of particular interest. She described the iron fertilization experiments conducted to date, including the materials and techniques used, noting that only one experiment ascertained the fate of the phytoplankton biomass with certainty. The results demonstrated that iron fertilization can increase chlorophyll (phytoplankton or 'plant') production within fertilized ocean patches, but that other nutrients can limit the effect, and that further research is needed to understand the effects of food webs on the process, and the effects of the process on food webs themselves.



Links between iron supply, marine productivity, sea surface temperature and CO_2 over time, from Alredo Martinez-Garcia et. al.

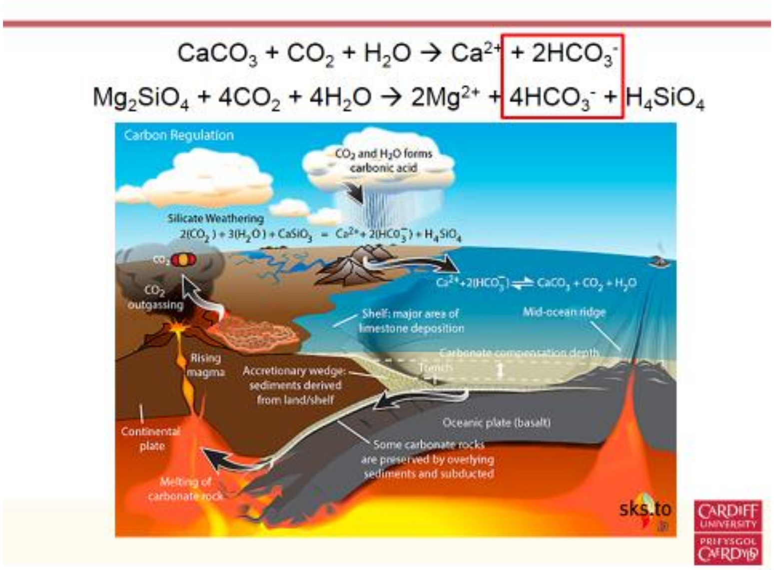
[10] Alfred Wegener Institute, Bremerhaven, Germany

Dr. Klaas also explained the potential risks associated with iron fertilization on both local scales (e.g. toxic blooms, dead zones) and global scales (e.g. reduced oxygen at depth, decreases in productivity outside fertilized patches, production of other greenhouse gases, etc), noting that the uncertainties surrounding the viability of ocean fertilization as a carbon sequestration technique add significant weight to the case for international oversight for all ocean fertilization activities. Dr. Klaas also said that it was very difficult to quantify what happens to the iron added in experiments, and its efficiency of use, and also noted that the species of algae that would respond to fertilization in any one case could not be predicted with confidence. She concluded that iron fertilization experiments are valuable research tools, and that while the risks of large scale fertilization are poorly constrained, understanding these risks is essential to understanding earth systems.

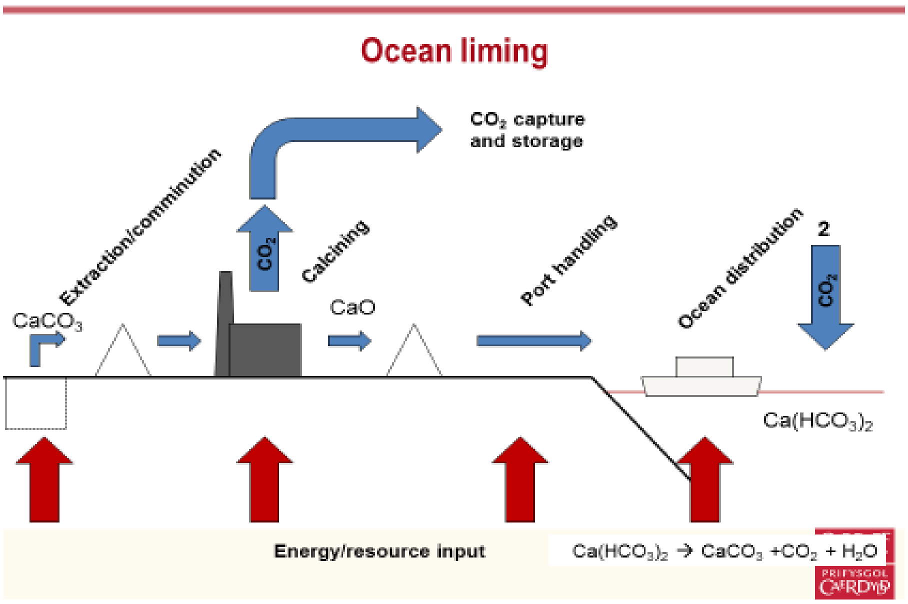


4 Ocean alkalinity modification – Dr. Phil Renforth[11]

Dr. Renforth discussed the global carbon cycle, and the role of ocean chemistry in regulating atmospheric carbon levels, and the biological effects of ocean acidification. He described the basic processes involved in potential marine geoengineering techniques aimed at increasing ocean alkalinity (or reducing ocean acidity). In general, terrestrial minerals (e.g. olivine) would be extracted and then subjected to 'enhanced weathering techniques' on land, or in the ocean.



The presentation highlighted the uncertainties associated with the costs, significant energy requirements, and intensive mining that would be required to conduct ocean alkalinity modification globally. He concluded that increasing ocean alkalinity is technically possible, but that uncertainties remain as to whether it is possible on a meaningful scale (i.e. a scale large enough to meaningfully reduce atmospheric carbon levels) or whether it could be used to counteract ocean acidification, and that side effects are probable.



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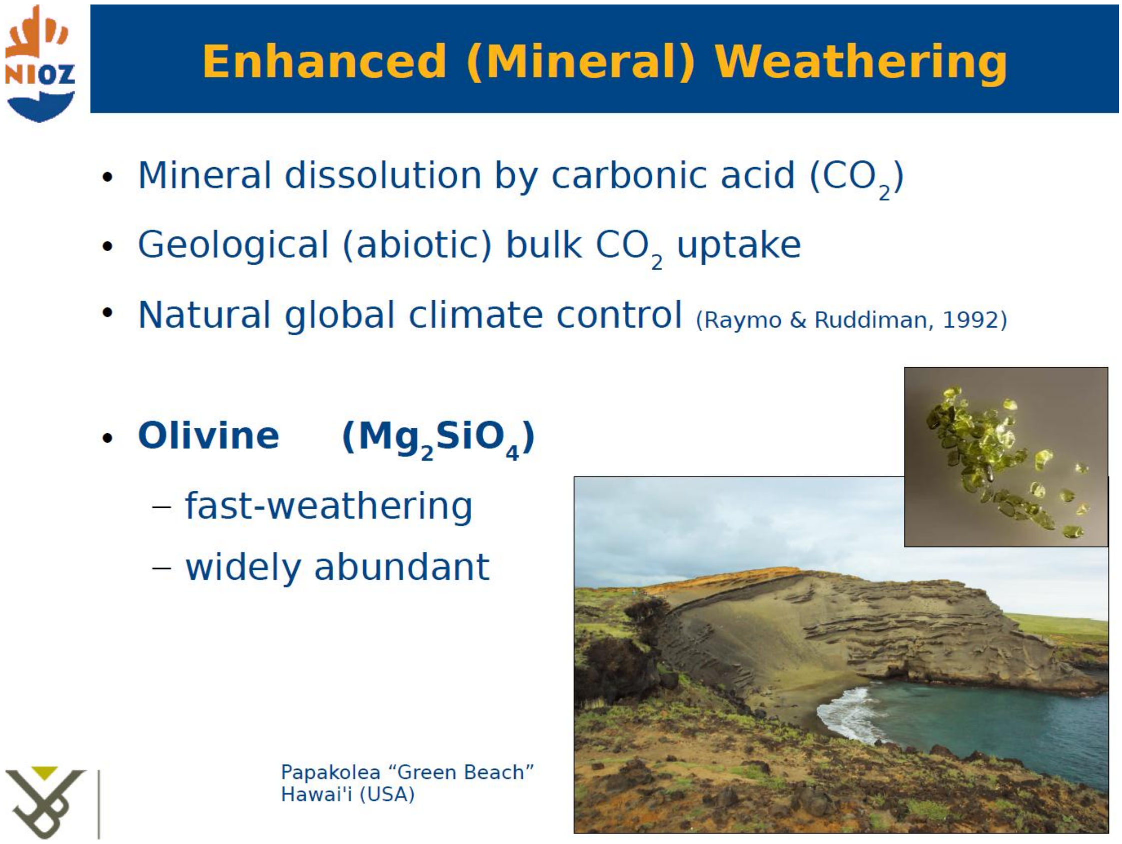
11 Cardiff University, United Kingdom

5 Enhanced mineral weathering as a marine geoengineering approach – Dr. Francesc Montserrat[12]

This presentation described research conducted into the processes, potential, and problems associated with enhanced mineral weathering. Olivine was examined as an abundant, fast-weathering mineral candidate for potential use in increasing ocean alkalinity. It was noted that earlier research has demonstrated that the grain size of olivine used had drastic effects on the efficiency of the carbon uptake process (e.g. production of smaller sized particles is associated with much higher carbon emissions during mining, crushing, and grinding). However, the presented research set out to use olivine of relatively large (ca. 150 micron) grain size, in order to simulate realistic scenarios. The research presented represents some of the first laboratory and field sediment experiments investigating olivine as a potential marine geoengineering technique. The results demonstrate that olivine dissolution in seawater causes alkalinisation of seawater and consequential CO_2 uptake and is theoretically very promising. However, further modelling and empirical research using a well-integrated interdisciplinary approach is needed to facilitate understanding and exploitation of the process geochemistry, and to predict and mitigate the potential ecosystem effects.



[12] Royal Netherlands Institute for Sea Research, the Netherlands

6 Marine geoengineering on the Canadian horizon: a survey of the future – Ms. Suzanne Agius[13]

Ms. Agius summarized research conducted by Dr. John Cullen[14] and provided an overview of marine geoengineering activities that might be undertaken by Canadians or in Canadian waters. For each activity identified, the likely efficacy, potential activity in the next ten years, and relative risk was assessed, resulting in the development of a table with links to publically available text and extensive background material that will be maintained, updated, and enhanced going forward into the future. Three general categories of activities were considered: carbon dioxide removal and sequestration, albedo modification, and ocean pumping. It was concluded that research into lower risk carbon dioxide removal activities is likely to accelerate, that no marine geoengineering activities appear to be imminent in terms of field research or commercial deployment, and that interest in field research and commercial deployment will likely increase over the next decade. A highly speculative list of the activities most likely to be field-tested in the next ten years included ocean alkalinity enhancement (most active area of research), artificial down-welling (high profile and secure research funding), and marine cloud brightening (very active area of research with some high profile funding).

7 Strategies for increasing ocean reflectance-marine albedo techniques – Professor Julian Evans[15]

In this presentation, Prof. Evans gave an overview of the reasons why increasing the ocean's ability to reflect light is of interest in counteracting some of the expected effects of global climate change, and noted natural phenomena that result in ocean reflectance (e.g. white caps, algal blooms resulting in foam production, refer figure below.). Approaching the issue from a materials' science perspective, Prof. Evans explained the energetic and physical / spatial requirements needed to increase ocean albedo. He presented the results of research considering artificial foam production with a range of materials, considering the degree to which each material increased reflectivity and its longevity in the ocean. Although the energy needed to create ocean foams is high, if they persist for a month, the average power to maintain 1 km^2 of foam would be relatively low. Initial experiments with proteins, polysaccharides and compatible gelling agents show that highly reflective and persistent sea water foams can be made in the laboratory. Research also suggests that thin layers of sea salt have promise as reflectors, but a means of deployment still needs to be found.

[13] Environment Canada, Canada
[14] Dalhousie University, Canada
[15] University College London, United Kingdom

Note that the implications of ocean foam generation on the biology and ecology of marine systems was not considered in this presentation - the focus was very much on the physics and not the biology.

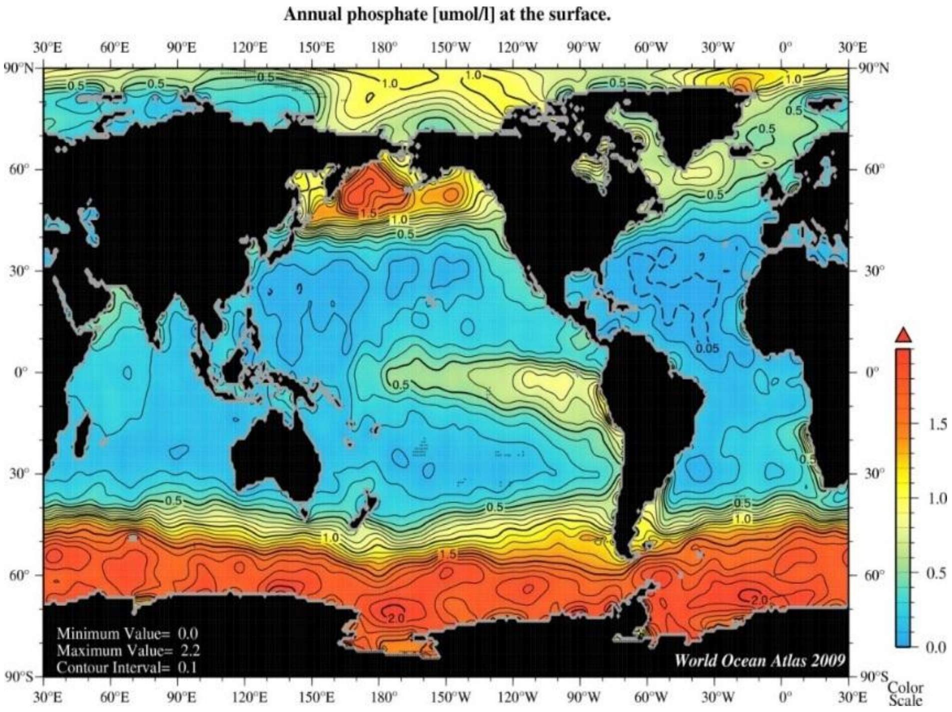
8 The physics, chemistry and biology of proposed marine geoengineering techniques – Mr. Tim Kruger[16]

Mr. Kruger began with an overview of proposed marine geoengineering techniques, including an exploration of their primary effects and often very large secondary effects. The techniques were divided into those that seek to increase planetary albedo (i.e. to make the earth reflect more light), which can result in physical, chemical and biological effects, and those that seek to enhance the capacity of the oceans to act as a sink for atmospheric carbon, which can also result in chemical and biological impacts. Mr. Kruger concluded by considering the boundaries of the London Convention and Protocol's jurisdiction in the governance of marine geoengineering. He noted that several activities would occur from land or in the atmosphere and therefore fall outside the London Convention and Protocol remit, but still have serious impacts on the oceans. Mr. Kruger also stressed that future research in the field needed a multi-disciplinary approach.

[16] Oxford University, United Kingdom

9 The price of carbon and the cost of macro and micronutrient fertilization of the ocean – Professor Ian S. F. Jones[17]

In this presentation, Prof. Jones examined the costs of ocean fertilization using macronutrients (e.g. iron) versus micronutrients (e.g. ammonia), and the costs of carbon capture and storage (CCS). He suggested that climate engineering will become necessary to mitigate the effects of global climate change, and that carbon dioxide removal techniques are becoming economically feasible. He asserted that ocean fertilization using iron and/or other macronutrients, and carbon capture and storage (CCS) are the most likely carbon dioxide removal candidates. Estimates of the relative costs of deploying these techniques in the year

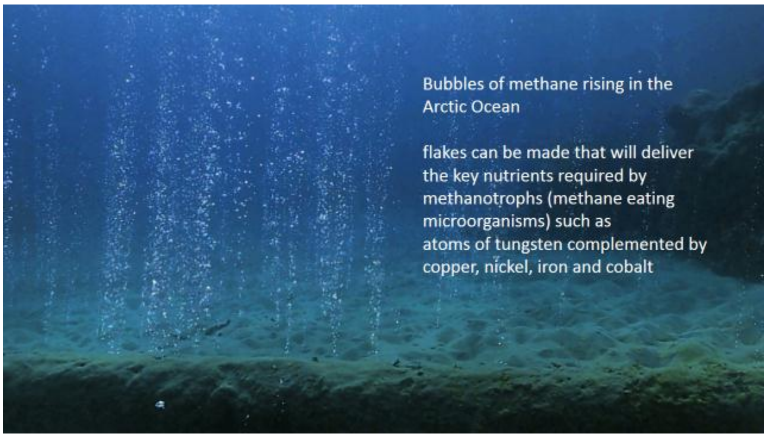


2000 were presented as follows: $475 per tonne of carbon dioxide captured using iron chloride, $20 per tonne of carbon dioxide captured using ammonia, $32 per tonne of carbon dioxide captured using urea, and $80~140 per tonne of carbon dioxide captured using CCS. Prof. Jones noted the higher efficacy of macronutrients versus iron at producing organic carbon (i.e. plant biomass), noting for example that fertilization by macronutrients produces 160 times as much organic carbon as iron, and that iron delivery costs about 160 times as much as nitrogen delivery. On the other hand he noted that the cost of raw materials followed the reverse trend, wherein nitrogen would cost $10 per tonne of carbon dioxide captured, while the cost of iron would be negligible. He considered phosphate as another macronutrient, but noted that it would be more expensive and is relatively limited in supply. In Professor Jones' view, macronutrient and micronutrient fertilization are different, and that macronutrient fertilization costs are within range, but that there have been only a few analyses of the associated risks, mostly comprised of general assertions without supporting detail; to make the risks explicit, more open ocean experiments are needed.

[17] University of Sydney, Australia

10 Ocean fertilization by buoyant flakes – Mr. Bru Pearce[18]

Mr. Pearce explained a proposal to fertilize the ocean using buoyant fertilizer flakes made from waste products (e.g. rice husks or mineral tailings). He asserted that the number of large fish and animals in the sea has been reduced by humans, diminishing the circulation of essential marine nutrients such as iron and phosphate and necessarily resulting in reduced planetary albedo. He suggested that a combination of a growth medium with sunlight and nutrients is needed for the biosphere to recapture atmospheric carbon. He noted that volcanic or desert dust trigger natural plankton blooms which provide the fastest creation of biomass on the planet. He also noted that these materials typically sink quickly through the water column, so that resulting plankton blooms die before stable ecosystems can form. He suggested that long term nutrient availability would be required to enable the survival of complex ecosystems, and that buoyant fertilizers could provide this. Flakes of rice husks and mineral tailings would have an approximate size of 0.3~0.5 cm^2, and be disseminated at a density of 10~100 per m^2 of ocean where they would float for 6~12 months providing nutrients and a habitat for micro-organisms. Mr. Pearce also suggested that flakes could be made to deliver the key nutrients required by methanotrophs (methane eating microorganisms). He suggested that flakes would be disseminated pneumatically and by the wind from bulk vessels. He concluded with a note that these ideas may be promising, but need to be further researched and developed.



View of the audience

[18] Envisionation, United Kingdom

Annex 1 – Programme

Thursday April 23 2015		*Speaker/Lecturer*
09:30-09:40	• **Opening –** Welcome and outline of the day	Chair/Moderator, Linda Porebski (Environment Canada)
09:40-10:00	• **Brief Summary of Marine Geoengineering Techniques**	Chris Vivian, Cefas
10:00-10:20	• **Ocean Carbon Capture and Storage (OCCS) – The concept and its implications as a geoengineering option**	Richard Lampitt, National Oceanography Centre
10:20-10:40	• **Ocean Iron Fertilization: overview and perspectives**	Christine Klaas, Alfred Wegener Institute, Bremerhaven
10:40-11:00	• **Panel discussion: Assessment, monitoring impacts and benefits – what are the biggest lessons learned thus far?**	
11.00-11.30	*Refreshments – Poster session on enhanced weathering and other emerging techniques*	
11:30-11:50	• **Ocean Alkalinity Modification**	Phil Renforth, Cardiff University
11:50-12:10	• **Enhanced mineral weathering as a marine geoengineering approach**	Francesc Montserrat, Royal Netherlands Institute For Sea Research
12:10-12:30	• **Marine Geoengineering on the Canadian Horizon – a survey of the future of marine geoengineering**	Suzanne Agius Environment Canada
12.30-14.30	*Lunch*	
14.30-14.50	• **Strategies for Increasing Ocean Reflectance-Marine albedo techniques**	Julian Evans, University College London
14:50-15:10	• **The Physics, Chemistry and Biology of Proposed Marine Geoengineering Techniques**	Tim Kruger, Oxford University
15:10-15:30	• **Ocean fertilization by buoyant flakes**	Bru Pearce, Envisionation
15:30-16:00	**Panel discussion 2: What will be most important to success in the next decade or two on marine geoengineering?**	
16.00-16.30	*Refreshments and Poster Session*	
16.30-17.30	• [extended informal discussion over posters or additional presentations if provided]	
17.30	*End of session*	

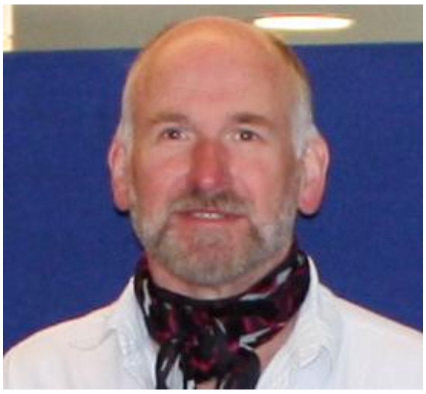
Annex 2 – About the moderators and speakers

Ms. Linda Porebski, Chief, Marine Protection Programs Section, Environment Canada

Linda is Chief, Marine Protection Programs Section, Environmental Assessment and Marine Programs Division in Environment Canada. She was elected as the Chairman of the Scientific Groups under the London Convention and Protocol in 2015. She advises on the marine environmental implications of dumping of wastes at sea and represents Canada at international fora.

Dr. Chris Vivian, National Marine Advisor, Center for Environment, Fisheries and Aquaculture Science, Lowestoft Laboratory Cefas Lowestoft Laboratory Pakefield Road Lowestoft.

Chris advises on the marine environmental implications of human activities at sea. Representing the United Kingdom at international fora e.g. OSPAR and London Convention/Protocol meetings. Past Chairman of the Scientific Groups of the London Convention and Protocol and of the Biodiversity Committee of OSPAR.



Dr. Richard Lampitt, National Oceanography Centre (NOC), Southampton, United Kingdom

Richard is an observational biogeochemist with a main focus on the factors that control the downward flux of material from the top of the ocean into the interior and from there to the seabed. Amongst other approaches this involves long term deployments of sediment traps deep in the water column (e.g. 3000m). A crucial factor is the export flux of material from the upper mixed layer and we have developed a drifting sediment trap which makes direct measurements of this flux, a rate which is notoriously difficult to measure. In order the understand the factors that determine the quantity and quality of material mediating this flux, continuous observations are required on a wide range of properties and processes occurring in the upper part of the water column. He also has increasing interest in issues of direct societal concern and in particular the ways in which the oceans may be encouraged to remove anthropogenic carbon dioxide from the atmosphere and he coordinates the NOC beacon theme on Geo-engineering which includes such activities.

Dr. Christine Klaas, Senior Scientist, Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany

Christine holds a PhD in biological oceanography at the Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany and an MSc in environmental protection with specialization in ecotoxicology at the Swiss Federal Institute of Technology, Lausanne, Switzerland. Her current research focusses on Southern Ocean plankton dynamics and its impact on biogeochemical cycles as well as on the impact of iron fertilization on carbon fluxes in the Southern Ocean.

Dr. Phil Renforth, Lecturer in Engineering Geology: Cardiff University, United Kingdom

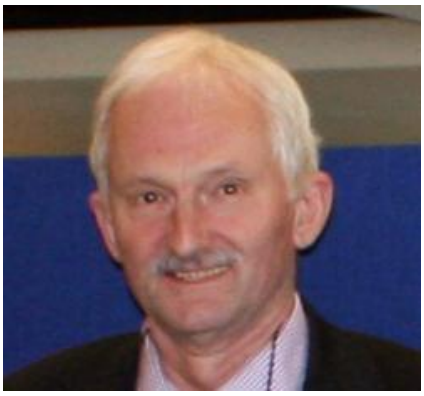
Phil's research interests are focused on using geochemical engineering to create, develop and assess novel solutions to major challenges facing human society. In particular relating to: carbonate formation in anthropogenic soils as a method of carbon sequestration and pollution remediation; and enhanced weathering and ocean alkalinity as carbon negative technologies.

Dr. Francesc Montserrat

Post-doctoral Guest Researcher at the Department of Ecosystem Studies, Royal Netherlands Institute of Sea Research and Postdoctoral Researcher at the Department of Analytical and Environmental Chemistry at the Vrije Universiteit Brussel, Belgium. He is currently working on Enhanced Mineral Weathering as a Carbon Dioxide Removal technique in the coastal zone. The focus is on using olivine dissolution to counteract ocean acidification effects in coastal and shelf seas. In addition and together with other researchers, he investigates the role of bioturbating benthic macrofauna in modulating fluxes of alkalinity between sediment and water.

Ms. Suzanne Agius, Senior Marine Advisor for Environment Canada

Ms. Agius holds a MSc Marine Biology and Ecotoxicology and is working in the Environmental Assessment and Marine Programs Division of Environment Canada which implements Canada's Protocol obligations domestically. She has also attended several IMO (London Convention and London Protocol) meetings as a member of the Canadian delegation, and assisted, as rapporteur a number of Working Groups under the London Protocol (including on ocean fertilization).



Professor Julian Evans, Department of Chemistry, University College London, United Kingdom

Professor Evans has a wide background in the materials sciences, starting out with a degree in industrial metallurgy followed by a Ph.D in polymer-metal adhesion and surface science, two years as a post-doc in adhesive bonding, a short period in the specialist printing industry and four years in the Ceramics Department at Leeds University. He worked for 14 years at Brunel University helping to set up a very successful group in ceramic processing using injection moulding, adapting other polymer processes for ceramics, then pioneering the direct ink-jet printing of ceramics and related techniques. He moved to Queen Mary, University of London in 1998 focusing on solid free-forming for applications in hard tissue scaffolds and metamaterials and starting work on polymer-clay nano-composites. He joined UCL in 2007 where he engages with the widely distributed Materials Science community throughout the College.

Mr. Tim Kruger, James Martin Fellow, Oxford Martin School Geoengineering Programme, University of Oxford.

Tim manages the Oxford Geoengineering Programme, an initiative of the Oxford Martin School, which assesses proposed techniques to counter climate change by either reflecting some of the sun's light back into space or by removing carbon dioxide from the atmosphere. Explores whether adding alkaline materials to the oceans can safely counter ocean acidification. Tim authored 'The Oxford Principles', a set of guidelines for the responsible conduct of geoengineering research.

Professor Ian Jones, Director, Ocean Technology Group at the University of Sydney, Australia

Professor Jones is Director of the Ocean Technology Group at the University of Sydney, Australia. An engineering graduate of University of New South Wales (UNSW) he took a Ph.D degree from the University of Waterloo, Canada. Dr Jones is a director of Earth Ocean & Space, a Sydney based environmental consultancy and has been a visiting professor at Sun Yat Sen, Tokyo, Copenhagen, Conception and Columbia University, New York, United States. He is the co-author of three books and is completing a monograph to be published by Cambridge University Press entitled "Engineering Strategies for Greenhouse Gas Mitigation". He has been Vice President of the International Association of the Physics of the Ocean and is presently a Councillor for the Engineering Committee for Oceanic Resources.

Mr. Bru Pearce, Director Envisionation Ltd, United Kingdom

Bru Pearce is a company director and project leader who has had a 25-year career in international resort development. He has conceived and delivered several major projects, engaged in all aspects of property and marina development including overall project management, sales and acquisition, political negotiations of planning and fiscal concessions, valuation, appraisal, financing, marketing, and the holistic economic development of the environments he has helped to create. Much of his work has involved adapting tourism based economies to market and environmental changes, by promoting; long stay tourism, educational, medical, retirement and life style relocation. A dedicated environmentalist he has been deeply involved in the promotion of renewable energy systems with particular interest in Pyrolysis for energy generation, waste disposal and the capture of atmospheric carbon. He sees renewable energy solutions as a vital part of achieving economic security especially in the Small Island State.

Annex 3 – Further reading

Brief Summary of Marine Geoengineering Techniques, Dr. C. M. G. Vivian http://www.cefas.defra.gov.uk/publications/files/20120213.

New Regulation of Marine Geo-Engineering and Ocean Fertilization. 28(4) International Journal of Marine and Coastal Law 729-736 (2013).

The London Convention and London Protocol – Marine Scientific Research and Ocean Fertilization. International Journal of Marine and Coastal Law 26(1):185-194 (2011).

Geo-engineering, the Law of the Sea, and Climate Change. Carbon and Climate Law Review 2009 (4):446-458 (2009).

Experimental activities that intentionally perturb the marine environment: implications for the marine environmental protection and marine scientific research provisions of the 1982 UN Convention on the Law of the Sea. Marine Policy 31(2):210-216 (2007).

Annex 4 – Glossary

IMO	International Maritime Organization
IOC	Intergovernmental Oceanographic Commission
UNESCO	United Nations Educational, Scientific and Cultural Organization
WMO	World Meteorological Organization
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
OCCS	Ocean Carbon Capture and Storage
OTEC	Ocean Thermal Energy Conversion