Climos Near Term Operating Plans

What will Climos' activities be over the next 12 to 24 months?

May 2008

Background

Climos intends to carry out a demonstration program of Ocean Iron Fertilization (OIF). We understand and appreciate the interest of scientists, regulators and thoughtful individuals in these activities. Many aspects of our planning depend on developments in the marine regulatory context, on financing, and on various logistics and schedules. As a result, the following overview is illustrative and details may change with time. However, in the interest of providing information and background to the variety of considerations involved in pursuing such a demonstration, we make this document available. We welcome any comments or advice on this document or its contents, as our progress thus far has been a result of countless suggestions and feedback from peers and others along the way. In addition, though we describe these elements serially, it should be understood that out of practical necessity many of them are being pursued in parallel.

In other documents provided to the London Convention/London Protocol SG we emphasized that the last 15 years represent a period of important basic scientific research that used OIF as a tool to study the role of iron in the productivity of the oceans and some aspects of the biological development of blooms and interactions with some parts of the foodweb. These remarkable experiments provided a wealth of new information about the productivity of the oceans, but were not well designed for questions related to the efficiency of carbon export, for air/sea exchange of CO2 and other biogenic gases, and for a variety of questions about the impact of OIF at larger scales. Because the experiments were so successful at stimulating blooms and because natural iron fertilization (e.g. Kerguelen Plateau) and some of the larger experiments (e.g. EIFEX) suggest that iron-stimulated blooms could sequester substantial amounts of carbon, the question remains concerning the potential of larger OIF blooms to function as a mitigation mechanism for CO2.

The potential sequestration ability of OIF and the impact of OIF at larger scales are different research questions – and they are intimately related to potential business opportunities to mitigate carbon. We know that these questions cannot be answered with a single large experiment. Instead, we view such an experiment as part of a new phase of research focused on efficacy and impact of moderate-sized experiments (~200 x 200 km). The demonstration program we are planning will emphasize research related to export and sequestration as well as environmental impact. Only with this information can scientists, regulators and the private sector understand whether larger scale deployment of OIF to mitigate CO2 would be successful and the nature of its impacts. If it cannot be demonstrated at this moderate scale that OIF sequesters carbon, and does so with negligible or acceptable ecosystem impacts, it will not be done at larger scales.

Permitting

Climos has made a commitment to obtaining a permit from a signatory to the International Maritime Organization London Convention on Ocean Dumping (IMO LC) prior to any actual demonstration experiment. If we cannot obtain one, we will not move forward. Because of this, our near term focus has been on the outreach and engagement necessary to communicate what we feel is the strong rationale for further scientifically-led, but privately funded, demonstrations. Our activities have included:

- The formation of a Scientific Advisory Board (SAB);
- Proposing elements of a "Code of Conduct" last year that lays out many of the requirements we will demand of ourselves;
- A presentation to delegates of the London Convention in November of 2007;
- The development of an early draft framework methodology for quantifying carbon export and permanence. This will evolve over the next year.
- The announcement of our engagement of Tetra Tech to produce a detailed Conceptual Model and Master Environmental Report for OIF that will form the basis of a comprehensive Environmental Impact Assessment;
- Preparation of detailed materials in advance of the London Convention Scientific Group Intercessional meeting in Guayaquil (including responses to the Canadian review and Greenpeace critique of OIF; and other notes concerning the legal status of OIF under the LC as well as the rationale for considering commercialization)

Following the completion of the Tetra Tech Conceptual Model and Master Environmental Report we intend to explore the possibility of obtaining a permit for a demonstration cruise from a favorable LC signatory that is operationally practical based on our chosen project location.

Site Selection

The initial iron fertilization paradigm we have chosen is fertilization of a HNLC (High Nutrient Low Chlorophyll) zone. HNLC areas have been the primary focus for eleven of the past twelve OIF research experiments. While other paradigms (such as fertilization to stimulate nitrogen fixation) have been discussed and debated, and while a valid rationale for exploring these paradigms may exist, we intend our first demonstration to be an HNLC OIF.

This selection narrows our potential choice of project locations. While the Equatorial Pacific is an HNLC region, we have chosen not to consider it for the first experiment because of the potential for generating N2O and because models suggest that at least some nutrient depletion could be an issue in this region. This has led us to focus on the North Pacific or Southern Ocean. Successful OIF experiments have been carried out in both areas. We will further limit our choice of sites to those sufficiently north of the latitude indicated by the Antarctic Treaty that our work would not affect the Antarctic. The primary constraint on the choice

between a North Pacific and Southern Ocean experiment is seasonality. Phytoplankton require adequate sunlight to grow in addition to adequate nutrient and this naturally limits any intentional stimulation of growth to the summer season.

The second constraint on site selection is distance from shore. OIF is generally not effective near land because iron is supplied by river runoff and/or resuspension of continental shelf sediment. Further, for carbon to be sequestered with sufficient permanence, water must be deep enough that the exported carbon is removed from further contact with the atmosphere at least 100 years. Because we want to be conservative about permanence, we will only consider project locations in deepwater (at least 2000 meters in depth and more likely ~4000 meters in depth or greater) and at least 500 kilometers away from the nearest land mass (and more likely at least 1000 to 1500 kilometers away). Both of these parameters are elements of the Code of Conduct we proposed.

The third constraint on site selection is proximity to an operating port that can provide an adequate source of working class vessels to perform the distribution of the iron sulfate to our specification. There are a limited number of countries that are both signatories to the London Convention, proximate to either Southern Ocean or North Pacific potential operating locations, and that have working ports of sufficient size to maintain a fleet of vessels available for hire and satisfactory to the work required. As of the writing of this document Climos has had no formal discussions with any nation for the purposes of permitting an OIF project under the London Convention.

Organization and Announcement of the Scientific Team

Climos will select and fund a Lead Scientist (Principal Investigator) to lead and coordinate the cruise on our behalf. Our preference is a Lead Scientist with previous experience in conducting OIF experiments. We are discussing the position with a small number of scientists. During the fall of 2008 Climos will hold a workshop for members of the international community familiar with OIF science to discuss the measurements and modeling necessary to quantify export/sequestration. The Pacific Marine Environment Laboratory of the U.S. National Oceanic and Atmospheric Administration (NOAA) has offered to host the workshop. A second workshop will emphasize measurements and modeling to quantify impacts of OIF. We anticipate that it will be held during winter 2008 or early spring 2009. We have been discussing co-sponsorship with an international global change program focused on interdisciplinary marine ecosystems.

Using the information and planning from the workshop the Lead Scientist will propose a scientific team to perform the demonstration cruise on our behalf. This team will be chosen for their scientific credentials and recognition within their research focus. Given the nature of active oceanographic research, it will be inevitable that some individuals that would like to participate in the cruise will have conflicts that prevent their participation.

Design of the Demonstration Project

Methodology:

Climos has begun drafting a methodology for OIF. The methodology will be developed further in collaboration with the science team based on the measurements and modeling recommended by the workshop. The methodology represents the method of quantifying the sequestration benefit of the OIF project. It is a formal technical document that will include, among other elements, a description and detailed calculations for:

- The distribution of the iron,
- The various instrumentation methods to be used,
- Defining the project boundary,
- The approach to measuring the 'baseline' conditions outside the project area,
- The approach(s) to measuring the resulting biomass inside the project boundary,
- The approach(s) to measuring the carbon export as well as the depth or various depths at which that carbon export will be measured,
- The method of integrating the various measurements as well as the statistical techniques employed for calculating overall carbon sequestration,
- The method of measuring any biogenic gasses with radiative forcing produced as a result of the project,
- The use of modeling techniques in combination with directly measured parameters to determine the drawdown of atmospheric CO2 as the surface ocean reequilibrates over time, as well as the effect on nutrients for subsequent productivity both inside the project area as well as in downstream locations.

Although this methodology will be patterned after documents required for carbon projects under the Clean Development Mechanism (CDM) of the Kyoto Protocol, the experiment cannot qualify as a Kyoto Protocol/CDM project, nor do we intend to propose it as one. We are using the methodology development to bring rigor to the description of the experiment for multiple audiences. The methodology is first and foremost a scientific document and must be developed in collaboration with scientists specializing in the various fields in question. It is, however, also a document which verifiers familiar with carbon markets would use to determine the quantity and permanence of any carbon sequestration achieved.

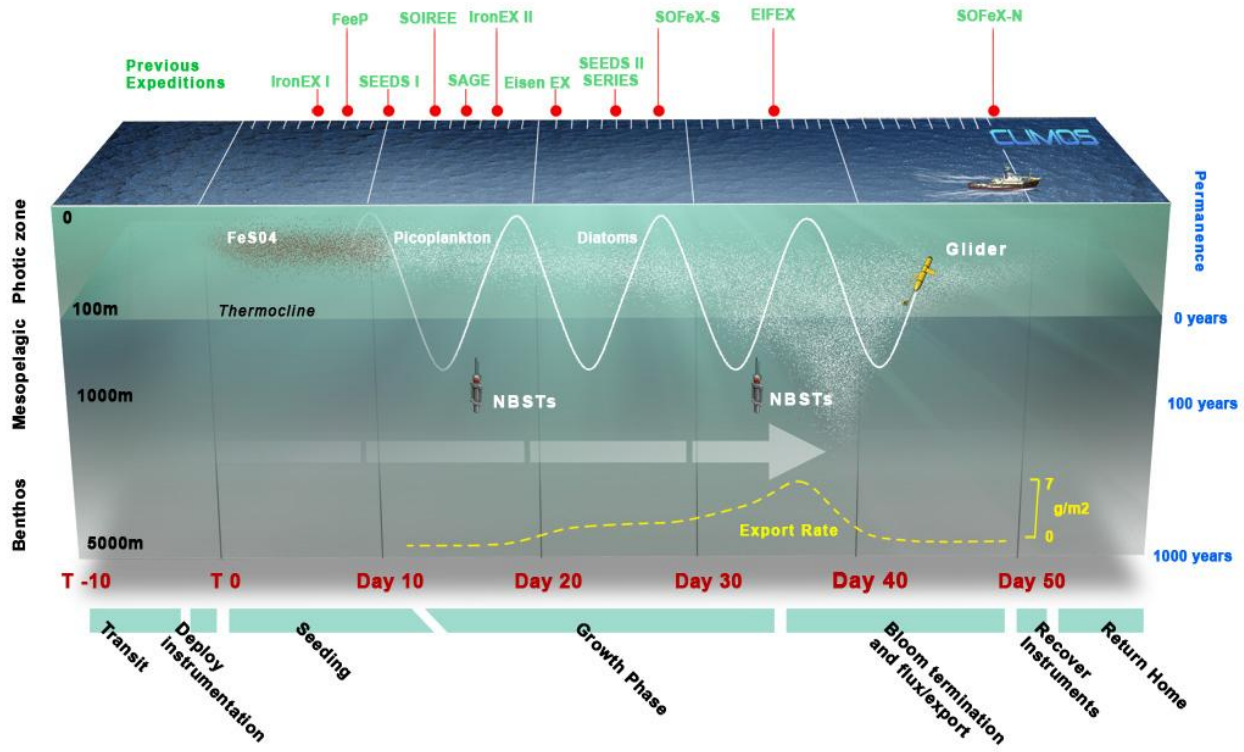
When complete, Climos will make the methodology publicly available for review by the international science community.

Scale:

Results from previous OIF experiments clearly highlight the need for a series of larger scale, second generation demonstrations to determine whether OIF might be an effective carbon mitigation technique. ((Boyd, Jickells *et al.* 2007), IOC ad hoc Group on OIF 2008, (Buesseler, Doney *et al.,* 2008)). The patch scales described in these documents range from 100x100 km to 200x200 km, approximately the dimension of mesoscale eddies. Conducting OIF experiments on this scale will greatly improve the likelihood that measurements in the patch have the minimum dilution with material outside the patch and will increase the statistical accuracy of carbon sequestration measurements.

Duration:

Early OIF projects had cruises that were long enough to observe bloom development. These cruises were often too short to capture the export phase and/or bloom dissipation. We anticipate that the scientific team will want to conduct measurements for about 70 days (including transit legs) from one the most capable and longest endurance classes of oceanographic research vessels.



Planning and Logistics in Preparation for a Demonstration Cruise

The research measurement platform:

The Climos demonstration project will involve funding an independent scientific team to conduct measurements for the experiment from a known research class vessel that is already outfitted with the basic facilities required by a sophisticated oceanographic research operation. As project location and timeframe become more established, we will work with the Lead Scientist to identify the research vessels that might be available and appropriate for the project based on location, duration, instrumentation to be deployed, number of scientific crew, seasonality and likely sea state.

Identification of a source of iron sulfate:

Climos will contract with a supplier of iron sulfate (most likely in monohydrate form, i.e. FeSO4 H2O). We will use a vendor that can supply a credible purity analysis of that material. In general terms, we intend to use an iron sulfate compound that is manufactured for the purpose of fertilization activities. Iron sulfate is normally used for a variety of land-based applications such as trace nutrient in plant fertilizer and nutritional supplements for animals. While the iron sulfate does often originally derive from a co-product of either steel manufacturing or titanium dioxide manufacturing, commercial formulators according to specifications appropriate for the use intended further process it. Climos will obtain analyses and provide those to interested parties to ascertain levels of any other trace materials in the solution that will be used.

A full materials report is available separately.

Table 1 indicates the impurity analysis available from a typical provider for FeSO4-H2O, the concentrations of these impurities that would result in a 5 nmol iron sulfate solution, and the normal concentrations of these metals in seawater.

Element	Maximum concentration in $Fe(SO_4)$ (ppm)	Concentration in 5 nmol $FeSO_4$-H_2O solution (mg/l)	Concentration in seawater (mg/l)
As	1	0.000001	2.60
Cd	2	0.000002	0.11
Cr	20	0.000017	0.20
Cu	17	0.000014	0.90
Pb	17	0.000014	0.03
Mg	9600	0.008156	1290000.00
Mn	2700	0.002294	0.40
Ni	85	0.000072	6.60
Zn	2000	0.001699	5.00

Contracting for distribution vessels:

An experiment of the size above discussed by the science community would require weeks to fertilize with one ship. Such a prolonged fertilization time would mean that one end of the patch would be in a substantially different phase of bloom and export than the opposite end. This would introduce several complexities for interpretation of the results. For this reason we will use multiple ships to fertilize the patch. The number will depend on the final size of experiment chosen. Because fertilization is an operational activity, Climos will take responsibility for contracting the ships that will distribute iron and obtain the necessary permits for distribution.

The Project

A solution of iron sulfate, a chelator (HCl), and ocean water will be mixed into a carefully defined ocean patch for the purpose of stimulating the growth of naturally occurring short-lived phytoplankton blooms.

Before being introduced to the ocean, the iron sulfate compound will be diluted into a solution consisting of seawater and a small amount of hydrochloric acid (HCl) that will chelate the iron sulfate to increase its solubility and prevent its rapid precipitation out of seawater. The extremely weak concentration of the HCl will be more than compensated for by the increase in pH achieved through the absorption of CO2 by phytoplankton stimulated through the bloom itself. The target concentration for the FeSO4 in seawater will be approximately 4 nmol/kg over the patch area. This is an amount that has been the target for several previous experiments and is approximately equal to the iron flux from dust during one year. This placement of iron will be performed by separate vessel(s) ('distribution ships') from the research vessel ('measurement ship') that will perform measurements. It is likely that more than one distribution ship will be used.

A research vessel ('measurement ship') will deploy a variety of instruments to measure both bloom development as well as subsequent export (i.e. sequestration) of that biomass to depth.

All instrumentation deployed will be recoverable.

The project will consist of transit legs both to and from the project location by all vessels, instrument deployment, which make take several days, initial distribution or 'seeding' of up to several weeks (followed by the departure of the distribution ships), bloom observation, and export measurement.

In addition to the measurement of carbon sequestration efficiency, an emphasis of the cruise will be on biologic impact. A variety of samples and measurements will be taken before, during and after the demonstration, both inside as well as outside the project area in order to characterize the biologic and ecosystem response.

Project evaluation:

Climos plans several activities that will ensure proper evaluation of the results of the experiment:

- All data generated from the cruise will be transferred immediately by the Lead Scientist to a publicly held database to ensure transparency and so that anyone can evaluate the measurements and any results and conclusions drawn from them.
- All participants and users of data will be encouraged to publish their results in the open scientific literature and to discuss them at scientific meetings and workshops.
- The Surface Ocean Lower Atmosphere Study (SOLAS) and the Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) programs of the International Exosphere Biosphere Program (IGBP) are discussing establishment of a procedure whereby SOLAS and IMBER could provide an independent evaluation of the science results of the experiment(s) at an appropriate time after the

experiment(s). The evaluation will provide opportunities for the participants on the science team to present their results, for individuals who were not on the cruise but using data from the cruise to present results, and for the international science community interested in the cruise to discuss results with participants and other data users. We very much appreciate the collaboration of SOLAS, the international program that has done so much to foster the previous OIF experiments, and IMBER, an international program focused on understanding the impact of large scale changes in ocean forcing, in facilitating review by the international science community.

London Convention Briefing

All published data, results of the workshop, and published data will be made available to the LC/LP and we will be prepared to make presentations to the LC/LP so that they can understand the results of the experiment.

Boyd, P. W., T. Jickells, *et al.* (2007). "Mesoscale Iron Enrichment Experiments 1993-2005: Synthesis and Future Directions." Science 315(5812): 612.

Buesseler, K. O., S. C. Doney, *et al.* (2008). "Ocean Iron Fertilization--Moving Forward in a Sea of Uncertainty." Science 319(5860): 162.

