➧ with all physical sampling of the microlayer is that bulk seawater is inevitably collected along with the very thin surface layer. The design of sampling instruments and the difficulties associated with making such measurements in bad weather were discussed.

After the presentations, the discussion began in earnest, directed initially by the content of the presentations. The discussion rapidly moved onto surface films (the 'chemical microlayer' as described above). These are of great interest to SOLAS science for a number of reasons: i) surface films have been shown to inhibit the rate of air-sea trace gas exchange; ii) the chemical differences between microlayer and bulk seawater may mean that concentration-based estimates of air-sea trace gas flux are substantially in error and iii) they are highly variable with geographic location and sea state.

The outcome of the discussion session was a set of focussed questions on sea-surface microlayer science (mostly concerned with the surface film) . There was speculative discussion on the answers to these questions, but the general feeling was that very little was known about a phenomenon that has potentially great significance to the science of air-sea interaction. The questions raised are shown in the box below.

How do we define the depth of the microlayer; and how can we sample it representatively?

Are surface films present in the open ocean to a degree that they significantly affect gas transfer rates?

What is the effect of phytoplankton blooms on the presence or thickness of surface films?

Is there a potentially significant source of DOC to the atmosphere from aerosols formed from the ocean surface?

Is there a simple parameter that can be measured non-invasively to determine the presence or extent of surface films in the context of air-sea gas flux measurements?

Mesocosm perturbation experiments and the sensitivity of marine biological systems to global change

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A strong focus for the implementation of SOLAS-related research lies in the combination of i) process studies of contemporary forcings in the field ii) manipulative experiments examining the ocean's responses to projected future forcings and iii) coupled biogeochemical ecosystem modelling. Applying these three approaches in an interactive manner, as outlined in Focus 3 of the SOLAS Implementation Plan, is required to achieve realistic projections of future transformations in the ocean in response to global change.

Manipulative experiments can be executed on various scales ranging from well-controlled laboratory experiments to whole ecosystem perturbation studies. For an integrated understanding of marine ecosystem responses to global change, there is a particular need for manipulative experiments on the community level. This can be achieved both in large enclosures and open ocean in situ experiments. While mesoscale in situ experiments, like the iron fertilization studies, provide the best representation of whole ecosystems, logistically they are not always practical or feasible for other projected forcings such as CO_2-induced ocean acidification, increasing temperature or changes in surface layer stratification and nutrient supply. Mesocosm perturbation studies, such as those recently conducted in the Bergen Large Scale Mesocosm Facilities (Fig. 1), offer a reasonable alternative, allowing the manipulation of complex ecosystems in a semi-natural setting under a range of oceanographic settings. To further develop this research tool and to ensure comparability of different mesocosm studies, Focus 3 of the SOLAS Implementation Plan therefore includes the following recommendations:

• SOLAS will encourage technological improvements for open ocean manipulative experiments, including developing open ocean mesocosm facilities.

• SOLAS will convene a workshop to develop guidelines to ensure comparability of and quality standards for mesocosm experiments.

To start this process, a discussion forum was held at the SOLAS Conference in Halifax to address a number of questions relevant to the design and interpretation of mesocosm experiments. Points of discussion included:

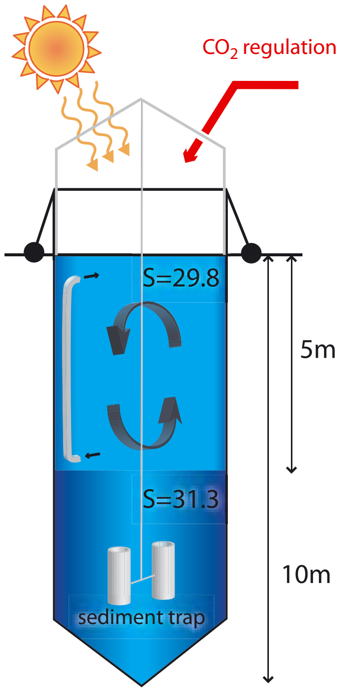
1. What questions can be addressed in mesocosm perturbation studies?

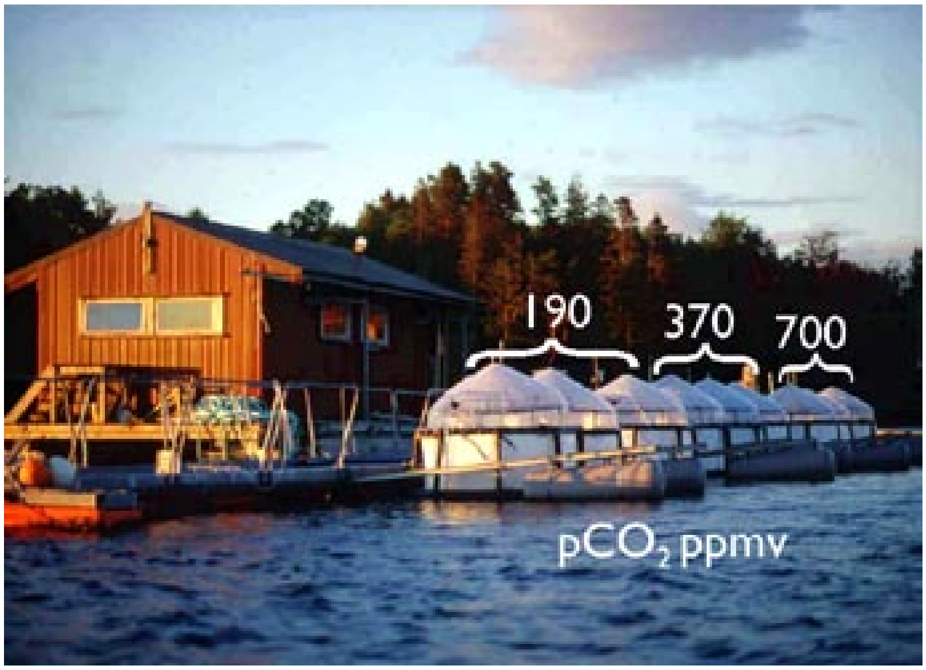
2. How representative are mesocosms for the natural system?

3. Can replication be assured in mesocosm experiments?

4. What is the optimal size for the plankton community considered?

5. How can we standardize mesocosm perturbation studies?





Pelagic Ecosystem CO_2 Enrichment (PeECE) experiment conducted in the mesocosm facilities of the University of Bergen, Norway. Triplicate mesocosms were maintained at glacial, present-day and projected year 2100 CO_2 conditions (IPCC IS92a). For further details see http://spectrum.ifm.uni-kiel.de/peece/index.htm

The discussion highlighted some of the main promises and limitations of mesocosm experiments. Possible applications (question 1) include i) pH/ CO_2 perturbations, ii) macronutrient and/or trace element enrichments, iii) nutrient ratio experiments, iv) changes in redox state, v) dust additions, vi) temperature perturbations, vii) zooplankton exclusions, etc. Concerning question 2, it was emphasized that mesocosms do not replicate the natural system. Wall effects, differences in the mixing regime and turbulence level, and in some cases the exclusion of higher trophic levels create an environment which differs from ambient conditions. Small differences in the starting conditions between individual mesocosms, such as in the seed population, may cause large differences in the final community composition. The interpretation of mesocosm results therefore crucially depends on replicate controls and treatments (question 3). Even then, stochastic effects and differences in species composition may sometimes obscure the interpretation of the observed responses. The specific design and optimal size of mesocosms (question 4) obviously depends on the scientific questions to be addressed and should carefully consider the life cycle and behavioural characteristics of the various components of the ecosystem studied. In some cases it may be preferable to deliberately exclude certain (higher) trophic levels instead of including them in non-representative numbers or under unnatural conditions.

A main limitation pertinent to all manipulative experiments – independent of their size – is the time scale problem. Perturbation studies of the kind discussed here typically examine short term responses to strong and rapid perturbations of the environment. This excludes the potential of natural ecosystems for evolutionary adaptation or the migration of strains, species or communities better adapted to future forcings. Temporal and spatial constraints of perturbation studies also limit the use of this approach for integrative processes such as export, sequestration, and elemental recycling. In view of the pressing need to better understand ecosystem responses to future forcings, however, manipulative experiments at the community level will be indispensable in future programmes. In spite of their limitations, mesocosm perturbation experiments provide a necessary link between laboratory culture studies and open ocean in situ experiments. To ensure intercomparability and establish quality standards (question 5), a set of guidelines for best practice should be worked out by the mesocosm research community. The discussion forum at the SOLAS conference in Halifax was the first step in this direction, which will be followed up by a dedicated workshop planned for 2005. Future activities on this aspect should promote close coordination between SOLAS and other related programmes, such as IMBER, LOICZ and GLOBEC.