UK Surface Ocean – Lower Atmosphere Study (UK SOLAS)

Science Plan

1. Context

The overall aim of the UK SOLAS directed programme is to advance understanding of environmentally significant interactions between the atmosphere and ocean, focusing on material exchanges that involve ocean productivity, atmospheric composition and climate. The knowledge obtained will not only improve the predictability of climate change but will also give insights into the distribution and fate of persistent pollutants and other future environmental conditions – thereby helping to develop appropriate policy responses. The programme is funded by the Natural Environment Research Council at the level of £12.1m, including management costs, over the period 2004-2009.

The NERC-supported programme provides the main national science contribution to the international SOLAS initiative (SOLAS, 2004; www.solas-int.org), with similar research goals. This Science Plan emphasises elements identified in the original UK SOLAS thematic proposal, particularly those that: require an interdisciplinary approach; build on existing strengths of the UK community of atmospheric scientists, oceanographers, microbiologists and modellers (as developed by ACSOE, PRIME, M&FMB and COAPEC; see Appendix 1 for acronyms); and complement other major NERC programmes and initiatives (such as RAPID, QUEST, CASIX, AMT and NCAS). Other SOLAS-relevant activities carried out by UK researchers can also be formally recognised as part of the international effort; however, they are not constrained by this Science Plan, and may cover additional topics (e.g. sea ice).

Core issues for UK SOLAS are the biogeochemical and physical processes in the upper ocean and lower atmosphere that control chemical exchanges across the air-sea interface. These research problems will be investigated by hypothesis-driven studies, using ship and aircraft campaigns supplemented, as appropriate, by laboratory and mesocosm experiments. The spatial and temporal scaling-up of the process-oriented fieldwork will be achieved by remote sensing, time-series measurements, monitoring studies, and modelling, from local to basin-wide and global scales. Implementation issues are addressed in greater detail in the UK SOLAS Implementation Plan.

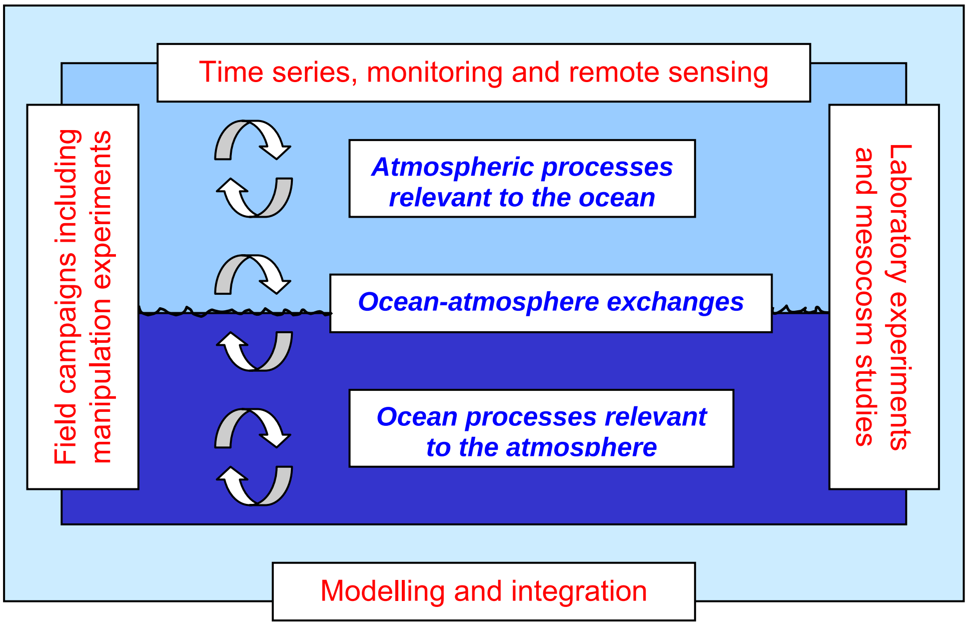
The linkages between the main components of the UK SOLAS programme are summarised conceptually in Fig 1 (below). Although highly simplified, this shows the need for a well-structured, integrated and community-wide approach, to address the dynamic behaviour of the coupled atmosphere/ocean system within an Earth System framework (NERC, 2002; Houghton *et al*, 2001).

2. Programme goals

Three 'high level' goals for UK SOLAS are:

- To advance our quantitative understanding of the mechanisms that control the rates of air-sea exchanges of gases, dust, nutrients, aerosols and solar radiation, and to use this information to improve estimates of air-sea exchanges.
- To evaluate how these exchanges impact the chemistry of the marine atmospheric boundary layer, the biogeochemistry of the ocean mixed layer, and feedback between the ocean and the atmosphere.
- To quantify the implications of these boundary-layer processes on the global climate system through developing improved predictive modelling capabilities.

Fig 1. Conceptual summary of UK SOLAS science structure



UK SOLAS goals provide an over-arching framework for the programme, and the basis for the more specific objectives and approaches presented below. It is likely that many of the component projects – i.e. research grant and training awards – supported through UK SOLAS will relate to more than one specific objective or approach, and interactions between component studies are strongly encouraged. Alternative science classifications are equally valid: indeed, an 'elemental' cross-cutting approach (based on air-sea cycling of, say, sulphur, iron, nitrogen, carbon or iodine, in both organic and inorganic forms) may prove useful for subsequent programme-wide integration and synthesis.

Whilst UK SOLAS is primarily directed at natural processes, some consideration of directly-produced anthropogenic emissions (e.g. combustion products from ship engines) may be relevant to budgets, modelling and chemical reactions in the marine atmosphere.

3. Research problems: processes and fluxes

3.1. Ocean processes relevant to the atmosphere

Objective i) To identify important trace gas production and loss processes in the surface ocean

For most trace gases, we have inadequate understanding of the dynamic processes affecting their generation (involving phytoplankton, zooplankton, bacteria, archaea, viruses and photochemistry) and breakdown (biological and photochemical). The balance between these production and loss rates not only determines the concentrations of dissolved trace gases in the upper ocean, but also is a major factor controlling their emission or uptake, hence affecting atmospheric concentrations. UK SOLAS will identify important production and loss processes for gases known to be climatically-important, e.g. DMS, N_2O, CH_4 and CO_2, also for other gases, such as alkyl nitrates, organo-halogens and oxygenated organics (Chuck *et al*., 2002; O'Dowd *et al*., 2002), that are relevant to wider air-quality considerations. For example, the diversity, abundance and activity of the major groups of microorganisms that are involved in trace gas biogeochemistry will be identified using conventional microbiology and molecular techniques, coupled with trace gas measurements (Malmstrom *et al*, 2004; Bodrossy *et al*, 2003). In addition, important chemical processes involved in trace gas production and loss such as photochemistry (Moore & Zafiriou, 1994) will be investigated.

[UK SOLAS research that addresses this objective will contribute to Focus 1 (Activities 1.2, 1.3), Focus 2 (Activity, 2.2) and Focus 3 (Activity 3.3) of the international SOLAS Science Plan and Implementation Strategy, see www.solas-int.org]

Objective ii) To determine the impact of dynamic physical, chemical and biological processes on trace gas production and breakdown in the marine environment,with particular emphasis on the microbial loop

Knowledge of the influence of physical, chemical and biological variations on trace gas dynamics is required to estimate present-day concentration fields and assess how these distributions are altered by regional (e.g. rain and dust deposition of Fe and N) and global (e.g. increased atmospheric CO_2, temperature and solar radiation) perturbations. For example, changes in the size structure, composition and ecological role of pelagic communities (both autotrophic and heterotrophic) are likely consequences of environmental change (eg Karl *et al*, 2001, Beaugrand & Reid, 2003). Hence it is important to quantify the production/consumption rates of key trace gases by different taxa of marine organisms, and assess how the various components of the microbial loop respond to physical and chemical changes in environmental conditions. In addition, DMS production has recently been linked to a specific algal stress response (Sunda *et al*, 2002) which may be induced by changes in the Earth's radiation budget. These interactions may involve complex ocean-atmosphere feedback loops: for example, the role of DMS in regulating the level of solar radiation reaching the Earth's surface, (Charlson *et al*, 1987). Whilst the potential for such effects is now widely recognised, there are major uncertainties regarding their quantitative importance during the next 50-100 years. UK SOLAS will investigate how environmental variation influences trace gas dynamics in surface waters and related feedback processes, through laboratory, mesocosm and/or field-based perturbation studies (see 4.1 and 4.2).

[Contributing to international SOLAS Focus 1 (Activities 1.2, 1.3), Focus 2 (Activity 2.2) and Focus 3 (Activity 3.3)]

3.2 Atmospheric processes relevant to the ocean

Objective iii) To improve understanding of the atmospheric transport, cycling and deposition of dust and nutrients

The lower atmosphere connects processes occurring on land and in the rest of the atmosphere to the ocean. These connections are two-way, delivering and receiving materials. Atmospheric deposition of dust provides nutrients that may be lacking from the surface ocean, with the potential to significantly enhance primary production, both directly and indirectly (the latter via Fe effects on N_2 fixation; Falkowski *et al*, 1998). However, predictions of biological responses are hindered by limitations in our understanding of atmospheric transport, cycling and deposition processes (Jickells & Spokes, 2001). For example, it is known that iron is supplied to the surface oceans by desert dusts (e.g. Baker *et al*, 2003) but accurate measurements, and even estimation, of this flux is very difficult. In addition, wet atmospheric nitrogen deposition may be a substantial fraction of the total (biologically active) nitrogen flux to the pelagic ocean; however, its sources and chemical form are not well known (Cornell *et al*, 1995, 2003). An improved understanding of how atmospheric deposition influences biogeochemistry is required, to allow predictions of how such processes will alter with future global change. UK SOLAS will address issues relating to the temporal and spatial variability of these depositions, other (micro-) nutrients involved, and their chemical transformations.

[Contributing to international SOLAS Focus 2 (Activity 2.3)]

Objective iv) To assess the importance of marine sources of aerosols and influences on their dynamics

Aerosols provide a major contribution to the uncertainty in total anthropogenic mean radiative forcing relative to pre-industrial times. Globally-averaged, aerosol forcing is estimated to be between -0.3 and -3.0 Wm^{-2} (direct and indirect), and our scientific understanding of such effects is classified as 'very low' by IPCC (Houghton *et al*, 2001). The direct climatic role of aerosols is due to the scattering and absorption of solar and thermal radiation, while indirect effects arise from their modification of micro-physical properties, contribution to cloud formation and effects on cloud properties. The sea-air transfer of trace gases and production of sea-spray are known to cause significant changes to aerosol properties above the ocean. UK SOLAS will investigate processes involving both sea-salt and non-sea-salt (nss) aerosols produced through ocean-atmosphere interactions

The ocean emits large quantities of sea-salt aerosols by spume droplets and the bursting of whitecap bubbles. In addition to their role as highly-efficient cloud condensation nuclei and their direct and indirect impacts upon the atmospheric radiation field, these particles release gases (e.g. volatile organic compounds, sulphur and halogen species) and provide surfaces for heterogeneous chemical reactions. In turn, the characteristics of these aerosols reflect their source and subsequent physical and chemical processing (Chameides & Stelson, 1992, O'Dowd *et al*, 1997). The exchange of sea-salt aerosol between the ocean and the atmosphere is regulated by a variety of physical forcings, which will be subject to climate-induced changes and which, in turn, feed back to the global climate. UK SOLAS will carry out investigations in to the source strengths, distributions and removal rates of sea-salt aerosols to reduce the substantial uncertainty in current estimates of the production and removal rates of both sea-salt and nss aerosols. For climate forcing, it is especially important to extend flux estimates to the smaller particle sizes (~0.1μm) important as cloud condensation nuclei. Furthermore, the extent to which organic compounds present in seawater, often as a surface film, influence particle production and microphysics, as well as the characteristics of the resultant aerosol, needs to be established.

In terms of nss aerosols, UK SOLAS is expected to investigate the production of new atmospheric particles by nucleation of volatile organic compounds and low-volatility products of iodine and sulphur. Sulphate derived from the oxidation of dimethylsulphide (Liss *et al*, 1997) and oxidized photolysis products (i.e. IO and OIO) of biogenic iodine (O'Dowd *et al*, 2002) are both known to be involved in new particle formation over the ocean. However, the degree to which this process leads to new aerosols or the growth of existing particles is uncertain. For example, what fraction of such aerosols acts as cloud condensation nuclei under the conditions typical of clouds in the marine atmosphere is a key question surrounding this research area. Burkholder *et al* (2004) used a modeling approach to show that observed IO and OIO concentrations are unlikely to result in significant aerosol production, whilst Hewitt *et al* (1997) found that a substantial fraction of the sulphate formed from DMS oxidation is neutralized by reaction with ammonia, forming ammonium sulphate aerosol. In addition, interactions between halogen and sulphur chemistry have been suggested to influence new particle formation in the marine boundary layer but have received little attention. For example, modelling studies have suggested that reactions between DMS and oxidation products of biogenic-bromine (i.e. BrO) reduce CCN formation (von Glasgow *et al*, 2002). UK SOLAS will improve knowledge of the reaction rates and pathways for the oxidation and photolysis processes required for climate-relevant modelling of particle concentrations and their effects.

[Contributing to international SOLAS Focus 1 (Activities 1.1, 1.3) and Focus 2 (Activity 2.3)]

Objective v) To determine the role of trace gas emissions in modifying the oxidising capacity of the atmosphere

The atmosphere's oxidising capacity, i.e. its ability to process trace gases and hence the magnitude of their radiative impact, depends on the concentrations of oxidising species such as OH and ozone. There are several marine influences leading to the modification of tropospheric ozone and OH, which result in changes in the lifetime of reactive greenhouse gases and other climatically significant gases such as DMS. A particularly important influence results from the release of active halogen species from sea salt aerosol (Cl and Br) and from alkyl iodides and bromides, and their subsequent photochemistry in the lower atmosphere (reviewed by Platt & Honninger, 2003). Quantification of the effect of reactive halogen on the atmosphere's oxidising capacity is a high priority for UK SOLAS.

[Contributing to international SOLAS Focus 1 (Activities 1.1, 1.3) and Focus 2 (Activity 2.3)]

3.3 Ocean-atmosphere exchanges

Objective vi) To reduce the existing uncertainty in the air-sea fluxes of trace gases

Air-sea fluxes are routinely calculated from the product of the concentration difference across the interface (ΔC) driving the exchange and the physical transport term, the gas transfer velocity (k) (eg Liss & Slater, 1974). Accurate quantifications of both ΔC and k are problematic and represent fundamental limitations on air-sea flux calculations over a range of scales.

Much of our present understanding of the controls on k is derived from theoretical work (e.g. Liss & Slater, 1974) and wind tunnel studies (Wanninkhof & Bliven, 1991), assuming that k is proportional to wind speed. However, the uncertainty for CO_2 is a factor of about two when k is parameterised in terms of wind-speed alone (Nightingale & Liss, 2004) – neglecting the possible effects of waves, bubbles, biologically-derived surfactants, rain and other physical variables. Studies indicating that such parameters affect k include Upstill-Goddard *et al* (2003) and Frew *et al* (1990); the latter observed a 55-70% reduction in air-sea gas exchange in the presence of phytoplankton-generated surfactants. However, these effects are insufficiently understood to be quantified in models or routinely incorporated into flux calculations.

The concentrations of reactive gases may exhibit significant vertical and horizontal structure in both the surface ocean and lower atmosphere, creating difficulties in calculating fluxes based on ΔC. Temperature gradients are important in this context: for example, Robertson & Watson (1992) calculated that the 'cool skin' effect at the sea surface may increase global CO_2 uptake by the oceans by c 40%. UK SOLAS will improve the assessment of appropriate values of ΔC by developing better understanding of the controlling physical, chemical and biological processes – to be achieved by 'direct' measurements at similar spatial/temporal resolution to the variation in environmental forcing. Sections 3.1 (marine processes), 3.2 (atmospheric processes) and the role of the microlayer (see below) are also relevant in this context.

[Contributing to international SOLAS Focus 2 (Activity 2.1)]

Objective vii) To determine the role of the sea surface microlayer in regulating material fluxes to the atmosphere.

The sea surface microlayer has unique microbiological, chemical and physical characteristics (Liss & Duce, 1997). For example, DMS concentrations in the top few mm may be twice as high as in underlying water samples (Yang, 1999). Microlayer water (and its contents, including bacteria; Leck & Bigg, 1999) is particularly likely to be introduced into the atmosphere as an aerosol, through bubble-bursting associated with breaking waves (film and jet droplets), mechanical tearing (spume droplets) and spilling over of wave crests (splash droplets). Furthermore, under calmer conditions, trace gases must pass through this interface when exchanging between the ocean and atmosphere – and, as indicated above, the transfer velocity k may be affected by surface film properties. Such microlayer effects are difficult to investigate, and hence poorly understood. Nevertheless, better knowledge of the properties of this interfacial boundary is vital for determining the role of ocean-atmosphere exchanges in global biogeochemistry. UK SOLAS will increase our understanding of the importance of the microlayer on surface ocean – lower atmosphere biogeochemistry. For example the development and use of phylogenetic and functional gene probes to determine microbial population structure and dynamics at the microlayer will allow a better understanding of the role of this novel community in regulating air-sea gas exchange.

[Contributing to international SOLAS Focus 2 (Activity 2.1)]

4. Research approaches: techniques and tools

The science-based specific objectives (i)- (vii) above will be addressed through linked fieldwork and laboratory experiments. Our understanding of the underlying processes will be further developed and tested through monitoring studies, remote sensing, modelling and data assimilation, as detailed below.

4.1. Aircraft and ship-based fieldwork, including manipulation experiments

Approach i) To conduct large-scale, multidisciplinary field campaigns based on hypothesis-testing and including simultaneous measurements in the surface ocean and lower atmosphere

Field experiments using state of the art techniques will directly address the issue of air-sea exchange, with major campaigns expected to be carried out in collaboration with the international SOLAS effort. Available techniques include multiple tracer releases, as pioneered by the UK community (Watson *et al*, 1991), and micro-meteorological techniques such as eddy correlation (as recently verified at sea for CO_2; McGillis *et al*, 2001). UK SOLAS provides the opportunity to develop the latter technique further, in conjunction with eddy accumulation and boundary layer gradient methods, to measure the fluxes of a range of gases and particles from ships, autonomous vehicles and/or from fixed platforms. By deploying these approaches simultaneously, together with physical observations, a quantitative assessment of their accuracy will be possible, which should greatly improve our ability to specify *k* under different sea states and with different surface film conditions (Nightingale *et al*, 2000); see 3.3 above.

In addition to studies of 'undisturbed' conditions, field manipulation experiments are envisaged. These experiments could include: addition of real or artificial dust, or selected elements, to the surface ocean; investigation of the effect of specific rain events; and the induction of small scale ocean upwelling (as being developed by Japan SOLAS). Such perturbation studies demand a highly interdisciplinary and often Lagrangian approach. To maximise their benefits, coordinated use of aircraft, ships and ground-based platforms is needed, preferably for at least 6-8 weeks. Purposeful tracers (eg SF_6) may be part of manipulation experiments, or as part of 'observational' process studies – not only to follow surface water movements, but also (potentially) for air mass tracking, to investigate the evolution of chemical reactions in the atmosphere under *in situ* conditions.

Atmospheric studies will make use of the new aircraft instruments available for measuring the physical and chemical nature of aerosols, radicals (OH, HO_2, RO_2), hydrocarbons and oxygenated and halogenated VOCs, as well as a full suite of 'standard' chemical species. In addition, deployment of a medium-sized tethered balloon would allow studies of boundary-layer structure and the altitude dependence of selected atmospheric constituents (Moore *et al*, 2003). A wide range of ground-based instruments is expected to be available for physical and chemical measurements, including wind and O_3 profilers.

The above measurements will be supported by meteorological data, derivations of air mass back trajectories, satellite data on ocean surface characteristics and atmospheric properties (see 4.3) and calculations based on chemistry/transport models (CTMs). Coupled with flux measurements to determine the local sea to air fluxes, this will allow assessment of the regional contribution to atmospheric composition at the measurement site. The resulting datasets are expected to be used in conjunction with detailed chemistry box models, incorporating both gas and aerosol phases, and CTMs to develop our understanding of the influence of ocean fluxes on aerosol formation, composition and evolution, and on gas phase processing.

Joint field campaigns with other UK and non-UK research programmes will be considered where appropriate. For example, working with international SOLAS and IGAC projects, the latter including the African Monsoon Multidisciplinary Analysis (AMMA) that has UK involvement and an overlapping timescale with UK SOLAS.

4.2 Laboratory and mesocosm work

Approach ii) To investigate key processes in greater detail through controlled, small-scale studies in the laboratory and mesocosms

Although results obtained from laboratory and mesocosm investigations are not necessarily transferable to the open ocean, they can provide important process information to guide field and modelling studies. For example, knowledge of the precursors and processes involved in the production of DMS in the pelagic environment was elucidated through laboratory studies (reviewed by Malin *et al*, 1994). UK SOLAS is therefore expected to use this type of research to investigate the sources and sinks (biological and chemical) of trace gases, the role of the sea surface microlayer in determining fluxes to and from the atmosphere (eg Upstill-Goddard et al 2003) and liquid phase chemical processes in the near-surface layers of the ocean. Laboratory and mesocosm experiments may also provide opportunities for perturbation studies (eg the response of surface ocean processes to doubled CO_2) where investigations in the 'free' pelagic environment are not possible.

Laboratory measurements relating to atmospheric processes may also provide kinetic data for gas phase and heterogeneous reactions which determine reactive halogen release; the production and loss of ozone; free radical steady states; and gas-to- particle conversion (including nucleation of aerosols). Data are required for the microphysical parameters controlling aerosol growth, scavenging and radiative properties. Standard techniques of cloud and aerosol physics, gas and liquid phase kinetics and physical chemistry, including advanced optical and mass spectrometric measurements are expected to be used. Such studies need to be targeted to produce transferable physico-chemical data and parameterisations for use in numerical models of the ocean-atmosphere interface region.

In addition, some experiments may cover both the aqueous and gaseous phases. For example, recent work by McFiggans *et al* (2004) showed how trace gas emissions from macro-algae (seaweeds) influence atmospheric particle formation in the presence of ozone. Studies of this type are important in demonstrating the links between ocean and atmosphere processes.

4.3 Time series studies, monitoring and remote sensing

Approach iii) To develop time series for marine and atmospheric observations (e.g. with AMT and CASIX) and, if feasible, establish a monitoring station at an open ocean site (with research users)

While intensive field campaigns can provide insights into the mechanisms of atmosphere-ocean interactions, they only provide snap-shots of seasonal changes, and cannot resolve annual and longer-term variability in oceanic trace production/consumption and aerosol concentrations over the oceans. Furthermore, their spatial coverage is necessarily limited. Observations at appropriate time-scales, preferably at the regional scale, are required to fully address these issues – both to develop models, e.g. on source emission processes, and to test their ability to hindcast and predict real-world events.

UK SOLAS access to NERC research ships and aircraft is likely to be limited to 2006 -2008, and fieldwork may not necessarily be in the same geographical location each year. Hence there is a strong case to widen temporal coverage via links to other, ongoing programmes. The Atlantic Meridionial Transect (AMT) observational series started in 1995, has involved 14 cruises to date (May 2004) and currently receives NERC consortium support (2002-06). AMT science aims (see www.pml.ac.uk/amt) closely match those of

UK SOLAS – providing considerable scope for joint work, building on existing marine datasets and expanding the range of atmospheric data collected.

Additional partnership arrangements with the Centre for Observation of Air-Sea Interactions and Fluxes (CASIX, www.pml.ac.uk/casix) would provide further added-value to the UK SOLAS programme. CASIX expertise includes the acquisition, processing and interpretation of remote sensing data relevant to marine processes. UK SOLAS will not try to replicate such activities. Instead, the programme intends to collaborate with CASIX in collecting 'ground truth' data over large spatial scales and the associated analyses.

There is a global lack of open-ocean, marine and atmospheric monitoring sites that record a comprehensive suite of biogeochemical measurements relevant to SOLAS science. Although northern hemisphere datasets for atmospheric parameters are available for Mace Head (west Ireland) and Weybourne (north Norfolk), with some associated research cruises and aircraft campaigns, these sites are subject to strong coastal and terrestrial influences (Carpenter *et al*, 1999; O'Dowd *et al*, 2002). UK SOLAS will therefore investigate the possibility of establishing a new monitoring station and, if viable, seek to establish such a facility − initially to be closely linked to programme field campaigns, and subsequently (with co-support) having a significantly longer lifetime. Possible sites are the Cape Verde Islands, Ascension Island and Bermuda; consideration may also be given to Brazilian islands (eg Ilha Fernando do Noronha), the Falklands and South Georgia.

4.4 Modelling and integration

Approach iv) To develop a suite of complementary models with the varying degrees of sophistication that are required to describe the processes, interactions and feedbacks relevant to UK SOLAS (jointly with Hadley Centre and QUEST)

Much of this effort is likely to involve close collaboration between the NERC scientific community (including BODC and BADC) and researchers at the Hadley Centre/Met Office. In order to maximise the scientific outcomes of the modelling component of UK SOLAS, extensive consultation between modellers and experimental scientists will be a prime consideration during planning of the fieldwork activities. Novel observations will need to offer a global perspective, consistent with the international SOLAS strategy. The incorporation of other relevant datasets, both historical and contemporary, into the modelling effort will enhance the value of new data. Recent examples include a compilation of ocean DMS measurements (Kettle *et al*, 1999), and information on upper ocean biogeochemistry for Atlantic transects via AMT cruises.

Existing data sets may, however, require modification/reworking to provide the necessary global perspective. UK SOLAS is therefore expected to support initiatives to identify existing relevant datasets, and/or compile new ones from existing measurements, reassembling these into forms suitable for both refining current parameterisations and models, and for developing new ones. These activities will be closely linked to the NERC programme on Quantifying and Understanding the Earth System (QUEST; www.nerc.ac.uk/funding/thematics/quest) and tested as appropriate in the Hadley Centre climate model.

5. Data management

UK SOLAS will follow NERC policy regarding data management, to ensure the longterm availability of data collected and thereby maximise the application and exploitation of programme results.

NERC Designated Data Centres (BADC and BODC) will be engaged early in programme planning and project implementation, and subsequently used for data checking and archiving − with costs covered from programme funds. After a period of sole access by PIs for publication preparation, data will be made available to other programme participants and the wider community. For further details, see UK SOLAS Data Management policy, available late 2004/early 2005.

6. Training

The interdisciplinarity, multi-institute and international nature of UK SOLAS offers excellent opportunities for younger researchers, and it is anticipated that a significant number of research studentships (for PhD training) will be supported. The participation of students in international SOLAS activities (e.g. SOLAS science conferences and Summer Schools) will also be strongly encouraged.

7. Work with Research Users and wider links

A major aim of the UKSOLAS programme will be to develop working relations with a wide range of business, governmental and non-governmental research users to play a major role in international SOLAS; and to establish appropriate links with related initiatives. The NERC Knowledge Transfer (KT) scheme will be used for this purpose, considering KT as a two-way process between academics and wider stakeholders, i.e. bringing knowledge from the latter into the programme as well as providing them with science results.

As already indicated above, UK SOLAS is strongly connected to international SOLAS. For example, Professor Peter Liss is the first chair of the SOLAS Scientific Steering Committee (2001-04, with possibility of renewal), and the SOLAS International Project Office and UK SOLAS Science Coordination team are co-located at UEA. In addition, UK SOLAS has good contacts with other SOLAS programmes (e.g. Canada, Germany), and either already has or is developing liaisons with other relevant international activities, such as AMMA, CLIVAR, ITOP and OASIS.

8. Project management

The UK SOLAS Steering Committee (Chair: Dr Howard Cattle) provides science direction and advice. The NERC Programme Administrator is Sarah Collinge; the NERC Science and Innovation Managers are Mike Webb and Andrew Kaye; and the Science Coordination team is Phil Williamson and Claire Hughes (UEA).

Appendix 1: Acronyms

ACSOE	Atmospheric Chemistry Studies in the Oceanic Environment (NERC thematic programme)
AMMA	African Monsoon Multidisciplinary Analysis
AMT	Atlantic Meridonial Transect (NERC consortium project)
BADC	British Atmospheric Data Centre
BODC	British Oceanographic Data Centre
CASIX	Centre for the observation of Air-Sea Interactions and Fluxes
CLIVAR	Climate Variability and Prediction Research Programme
COAPEC	Coupled Ocean-Atmosphere Processes and European Climate (NERC directed programme)
CTM	Chemical Transport Model
DMS	Dimethyl Sulphide
IGAC	International Global Atmospheric Chemistry project
IPCC	International Panel for Climate Change
ITOP	Inter-continental Transport of Ozone and Precursors
M&FMB	Marine and Freshwater Microbial Biodiversity (NERC directed programme)
NCAS	NERC Centres for Atmospheric Science
OASIS	Ocean-Atmosphere-Sea-Ice-Snowpack Interactions Project
PRIME	Plankton Reactivity in the Marine Environment (NERC thematic programme)
QUEST	Quantifying the Earth System
RAPID	Rapid Climate Change (NERC directed programme)
SOLAS	Surface Ocean – Lower Atmosphere Study
UEA	University of East Anglia
VOC	Volatile Organic Carbon

Appendix 2: References

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