SOLAS – SURFACE OCEAN LOWER ATMOSPHERIC STUDY

http://www.solas-int.org

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INTRODUCTION

SOLAS (Surface Ocean - Lower Atmosphere Study) is a new international research initiative that has as its goal: *To achieve quantitative understanding of the key biogeochemical-physical interactions and feedbacks between the ocean and the atmosphere, including how this coupled system affects and is affected by climate and environmental change*. The domain of SOLAS is focussed on processes at the air-sea interface and includes a natural emphasis on the atmospheric and upper-ocean boundary layers, while recognising that some of the processes to be studied will, of necessity, be linked to significantly greater height and depth scales. SOLAS research will cover all ocean areas including coastal seas. A fundamental characteristic of SOLAS is that the research is not only interdisciplinary (involving biogeochemistry, physics, mathematical modelling, etc.), but also involves closely coupled studies requiring marine and atmospheric scientists to work together. Such research will require a shift in attitude within the academic and funding communities, both of which are generally organised on a medium-by-medium basis in most countries.

SOLAS GOALS

The scope of the study is illustrated in Figure 1 and described in detail in the Science Plan and Implementation Strategy. The Science Plan component is largely based on the results of the International SOLAS Open Science Meeting held in Damp, Germany in February 2000, which involved more than 250 scientists from 22 different countries. The International Geosphere-Biosphere Programme (IGBP), Scientific Committee on Oceanic Research (SCOR), Commission on Atmospheric Chemistry and Global Pollution (CACGP) and the World Climate Research Programme (WCRP) endorse SOLAS and are sponsors of it.

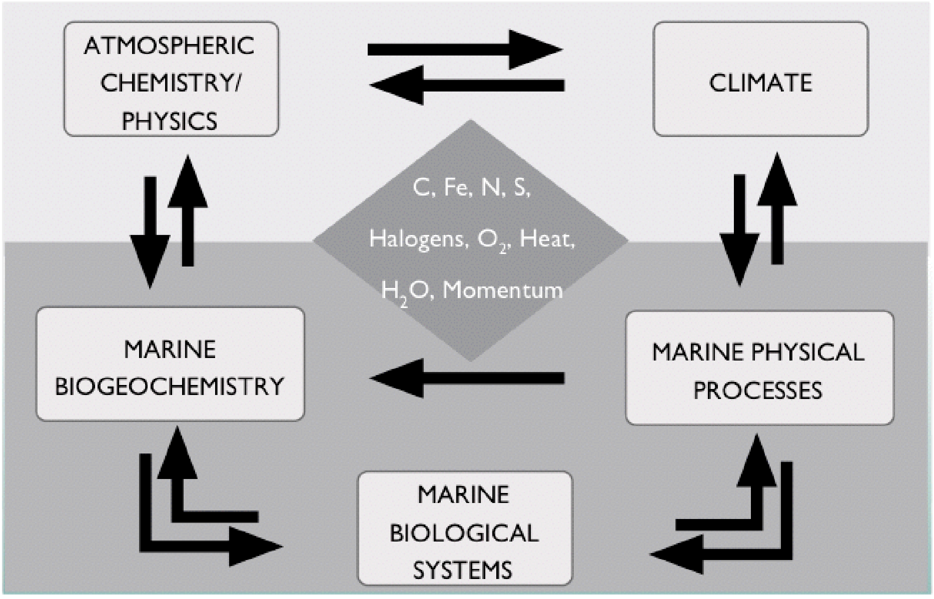

Figure 1. The scope of SOLAS (courtesy of Wendy Broadgate).

SOLAS FOCI

SOLAS deals with 3 scientific foci including: [1] Biogeochemical Interactions and Feedbacks Between Ocean and Atmosphere; [2] Exchange Processes at the Air-Sea Interface and the Role of Transport and Transformation in the Atmospheric and Oceanic Boundary Layers; and [3] Air-Sea Flux of CO_2 and Other Long-Lived Radiatively-Active Gases. Each focus is divided into several activities.

Focus 1: Biogeochemical Interactions and Feedbacks Between Ocean and Atmosphere

The objective of Focus 1 is to quantify feedback mechanisms involving biogeochemical coupling across the air-sea interface, which can only be achieved by studying the ocean and atmosphere in concert. These couplings include emissions of trace gases and particles and their reactions of importance in atmospheric chemistry and climate, and deposition of nutrients that control marine biological activity and carbon uptake.

Activity 1.1 Sea-salt Particle Formation and Transformations
Activity 1.2 Trace Gas Emissions and Photochemical Feedbacks
Activity 1.3 Dimethylsulphide and Climate
Activity 1.4 Iron and Marine Productivity
Activity 1.5 Ocean-Atmosphere Cycling of Nitrogen

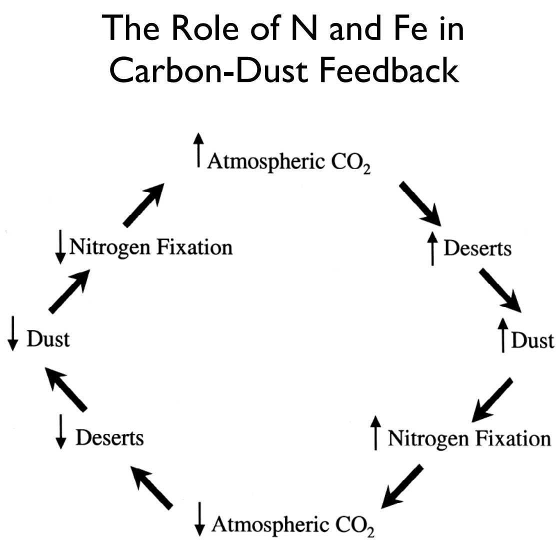

Figure 2. Courtesy of A. Michaels, USF.
Hypothesis of possible atmospheric impacts on marine biogeochemical processes. During interglacial periods, the planet is dryer with more deserts, dust and N_2 fixation. More Fe is utilized and there is consequently a greater pCO_2 drawdown. The cycle continues with a wetter climate and less deserts, dust, and Fe with a subsequent pCO_2 increase.

Focus 2: Exchange Processes at the Air-Sea Interface and the Role of Transport and Transformation in the Atmospheric and Oceanic Boundary Layers

The objective in Focus 2 is to develop a quantitative understanding of processes responsible for air-sea exchange of mass, momentum and energy to permit accurate calculation of regional and global fluxes. This requires establishing the dependence of these interfacial transfer mechanisms on physical, biological and chemical factors within the boundary layers, and the horizontal and vertical transport and transformation processes that regulate these exchanges.

Activity 2.1 Exchange Across the Air-Sea Interface
Activity 2.2 Processes in the Oceanic Boundary Layer
Activity 2.3 Processes in the Atmospheric Boundary Layer

Transport processes and environmental conditions in the SOLAS regime relevant to ocean and atmospheric boundary layer processes are shown in Figure 3. These processes and properties control the flux of climate relevant compounds across the ocean-atmospheric surface. The most direct method of measuring surface fluxes of atmospheric gases is the direct covariance, or eddy correlation, technique. It is not always feasible to use this method. For example, it may not be possible to measure fluctuations in a trace species with sufficient time response to resolve all the contributions to the flux. One alternative is to measure average differences in the quantity with height, and relate this to the flux by flux-gradient relationships derived from turbulence similarity theory. These techniques can be implemented either from a fixed observation site (e.g. a tower) or a mobile platform (e.g. a ship or aircraft). The advantages of fixed sites are that long-time averages can be obtained over particular locations, corrections for platform motions are not needed; and there are generally less stringent sensor time response requirements. The advantages of mobile ocean platforms are: the ability to measure over many different regimes, including remote areas; well-behaved turbulence statistics can be obtained in a shorter period of time and averaged over an area; and the ability of aircraft to resolve the vertical and horizontal structure throughout the MBL and above.

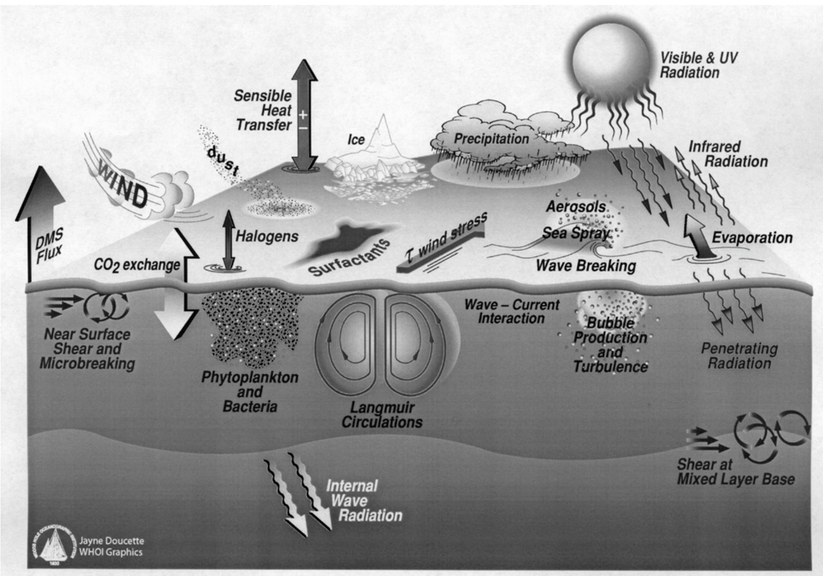

Figure 3: Processes in the surface ocean and lower atmosphere responsible for the exchange of momentum, heat and mass transport. The SOLAS science plan is organized into three sections: (1) processes at the oceanic-atmospheric interface; (2) processes within the ocean boundary layer; and (3) processes in the lower atmospheric boundary layer. Although processes are intimately coupled, this organization allows a focus on the dominant processes in each region.

Focus 3: Air-Sea Flux of CO_2 and Other Long-Lived Radiatively-Active Gases

The air-sea CO_2 flux is a key inter-reservoir exchange within the global carbon cycle. The oceans also play an important role in the global budgets of other long-lived radiatively-active gases, including N_2O and to some extent CH_4. The objective of Focus 3 is to characterise the air-sea flux of these gases and the boundary-layer mechanisms that drive them, in order to assess their sensitivity to variations in environmental forcing.

Activity 3.1 Geographic and Sub-Decadal Variability of Air-Sea CO_2 Fluxes

Activity 3.2 Surface Layer Carbon Transformations in the Oceans: Sensitivity to Global Change

Activity 3.3 Air-Sea Flux of N_2O and CH_4

SOCIETAL RELEVANCE

SOLAS can contribute to our understanding of the important role that the ocean-atmosphere interface plays in relation to issues important to society, including climate change, air quality, and the health of the ocean. For each of these topics, SOLAS will seek to develop collaborative research with related international projects. Likewise, the International Human Dimensions Programme on Global Environmental Change (IHDP) and SOLAS will work together to identify societal issues and important human drivers of changing biogeochemical fluxes, for example with respect to ethical, legal and financial implications of the research.

The Montreal and Kyoto Protocols marked a change in attitude within the international policy community to the issues of global change related to ozone and atmospheric carbon dioxide, respectively. Ozone depletion and greenhouse gas emissions are increasingly recognised as threats to the quality of human life, the global economy and natural ecosystems. Such threats require close observations and forecasts. As a practical matter, nations must plan to meet the commitments made in these agreements. Transparent and accountable verification of greenhouse and ozone-depleting gas sources and sinks is required. Within its area of research, SOLAS will develop the necessary scientific foundations to address these major societal issues.

However, at present, the political imperative is running well ahead of scientific knowledge. For example, models that interpret atmospheric and marine measurements of CO_2 show that the Northern Hemisphere land biota is taking up 1-2 PgC (petagrams of carbon, 1 PgC = 1 GtC) of atmospheric CO_2 per year, and the global ocean a similar amount. But beyond this understanding, little scientific consensus exists as to where (which continent or ocean) or why these sinks exist (what processes are responsible), or their variability on seasonal to decadal timescales. A second example of knowledge gaps is related to aerosols, which are now recognised as making a significant, but very poorly quantified, contribution to global climate change. However, their generation, chemistry and fate have received relatively little attention. Without a substantial maturing and deepening of our knowledge about this complex aerosol system, scientists will be unable to provide the verification techniques and forecasts of future trends that will make the Kyoto Protocol work. Similar arguments apply to ozone depletion where, in spite of the success of the Montreal Protocol, ozone recovery is being delayed by the continued increases in brominated gases and CFC (chlorofluorocarbon) replacements and, potentially, by global warming. This perturbation must be evaluated within the context of the large scale and uncertain air-sea exchange of biogenic halogen gases (Br, Cl, I). A further example is the case of proposals to fertilise large parts of the open oceans with iron in order to enhance the oceanic sink for CO_2; an issue for which proposed industrial application is running substantially ahead of scientific understanding. All these topics, together with many others, are major basic scientific issues in the SOLAS programme, the results of which will form the sound foundations for policy making in the coming years.

Simulations of future climate are only now beginning to incorporate the biological and chemical feedbacks that may arise as the atmosphere-ocean system changes in response to climate and environmental forcing. These simulations give divergent predictions, depending on which feedbacks are included and how they are modelled. Substantial changes in "natural" sources and sinks of climatically active gases are possible, indeed probable, once climate change effects become obvious. CO_2 is the most closely studied example, but dimethylsulphide (DMS) and other chemically active trace species such as organo-halogens may also have important effects, little addressed to date. These deficiencies lead to uncertainties in the timing and magnitude of global change effects by many decades, the social and economic implications of which are clearly profound. Adaptation strategies are highly dependent on the timescales of change. SOLAS is designed to address these issues, with the purpose of substantially reducing the uncertainties in our predictions of the timing and effects of future climate change.

SOLAS and the GLOBAL CARBON CYCLE

SOLAS cannot address all issues related to the ocean's present and future role in the global carbon cycle. Rather, it will address an important subset of carbon-cycle issues that are compatible with its overall goals, domain and technical approaches. These topics can be summarised as:

- Quantification of the present-day exchange of CO_2 and carbon-related properties between the atmosphere and the surface ocean.
- Understanding of surface-layer ocean processes that can change the future air-sea flux of CO_2, with potential implications for altered sequestration of carbon within the ocean.

SOLAS will focus on providing a description of the contemporary geographical and temporal structure and variation of air-sea CO_2 fluxes, as well as mechanistic understanding of surface-layer processes that determine these fluxes, both now and in the future. This should include a strong emphasis on continental margins where forcing and fluxes can be particularly large. These limited SOLAS objectives will provide a foundation for broader global carbon cycle science activities in the Global Carbon Project (GCP), particularly for the evaluation of, and parameterisation of processes in, the models required to predict future ocean carbon sequestration.

INTERDISCIPLINARITY and INTEGRATION

More than is usually the case, meaningful developments in SOLAS will depend on research that is not only interdisciplinary, but also involves closely coordinated field studies in which the different research components are combined so as to produce comprehensive data sets.

Achieving understanding of processes that occur at the ocean-atmosphere interface will require an enhanced level of cooperation in planning and execution of research among many different disciplines in the environmental sciences. The success of SOLAS will depend on the effectiveness of such cooperation and ability to integrate measurements and analyses of many different types.

These challenges require some educational efforts, such as summer schools, to bring together young and established researchers from countries with developed and developing science bases for the mutual exchange of ideas and experience. In addition and most importantly, research involving the coherent study of linkages between environmental compartments (in the case of SOLAS, atmosphere and oceans) will require a shift in attitude within the academic community and research funding agencies, both of which are generally organised on a medium-by-medium basis in most countries. Bridging such barriers is vital in order to fully understand climate and global change.