Comprehensive Earth System Modelling: Air-sea flux treatments and climate impacts

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Several new climate, carbon and biogeochemical modelling efforts that require multi-Tera flop computational resources will be discussed within the context of SOLAS related climate science and high performance computing. This session seeks contributions that evaluate and describe next generation Earth system models especially those that include specific biogeochemical processes and feedbacks in the air-sea climate system. Fully-coupled Earth system models -in both the biogeochemical and physical sense- that specifically track particle and trace gas exchange between the ocean and atmosphere, are critical in understanding and predicting future Earth climate. As part of the Climate Modelling in US SOLAS (CLIMIS) project and in the UK and EU SOLAS projects we encourage contributions form the modelling fields of ocean physics, ocean ecosystems, air-sea fluxes and atmospheric chemistry, radiation and physics. In particular, oceanic ecosystem models that describe and predict the carbon cycle and several other biogeochemical tracers that impact atmospheric chemistry and climate variability are encouraged to be described in this session.

SOLAS in the Southeast Pacific – VOCALS

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Climate models do a very poor job of predicting rainfall, cloudiness, and SST in the SE Pacific off of Chile and Peru. Several lines of evidence suggest that one of the major problems is the inability of these models to simulate the interactions between cloudiness, aerosols, surface fluxes of biogenic gases like DMS, biological activity, and nutrients in upwelling waters. In an attempt to provide measurements that can improve these models, the CLIVAR/VAMOS program and SOLAS have been planning the VAMOS Ocean Cloud Atmosphere Land Study Regional Experiment, VOCALS-REx. An intensive experiment is being planned for October of 2008, involving ships, aircraft, satellites, and land sites from several countries.

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The errors in modeled radiation budgets derive in part from Pockets of Open Cells, POCs, which open up when drizzle scavenges CCN particles. The regrowth of CCN that allow these POCs to refill with clouds depends on surface fluxes of DMS (and possibly organic vapors), which in turn may be modified by the increased insolation the POCs create. It is clear that the processes described by the CLAW hypothesis are the key to understanding and accurately modeling the energy balance this region.
The existing 2008 REx intensive plan includes only very limited studies of the biological and chemical factors controlling gas fluxes and aerosol growth. Space on ships is a major constraint. Participants in this section will discuss both how we could augment the 2008 experiment and the possibility of planning a follow-on project that would test several parts of the CLAW hypothesis in this region. The interface-and-up understanding gained from VOCALS-REx could enable an experiment with a greater focus on the interface-and-below issues. For example, we might use the natural light variation caused by POCs to look for responses in the biology and fluxes. SOLAS is the ideal group to plan an experiment that would complement the physics-oriented REx program initially envisioned by VAMOS.

Biogeochemical cycling and the sea surface microlayer

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The sea surface microlayer is the physical boundary between the upper ocean and the lower atmosphere and is therefore at the heart of SOLAS research. At this interface, a broad range of biogeochemical interactions take place which are of wide global significance, including production of dimethylsulfide, responses to atmospheric dust deposition, climatic forcing by sea-salt particle aerosol production and sea-air gas transfer. The proposed aim of this discussion session is to take a truly unified view of biogeochemical processes which involve the sea surface microlayer, surface ocean and lower atmosphere. Emphasis will be placed on particular marine 'events', such as phytoplankton blooms, in order to act as foci for discussion. Presentations and discussion will be targeted specifically to include participants from all disciplines. Researchers from all scientific fields working at this interface are sought, to contribute and actively challenge themselves and others in a wider understanding of biogeochemical processing in the sea surface microlayer.

SOLAS and the Paleo-Ocean

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Paleoceanographic research aims to understand marine processes during past times when environmental conditions were different from those today and from the period of instrumental measurement. SOLAS research provides highly valuable information on current systems, which is fundamental for an accurate interpretation of past-ocean reconstructions. Conversely, paleoceanography offers a unique possibility to the SOLAS community to test hypotheses on the sensitivity and response of different systems to changing boundary conditions. Accordingly, it would be mutually beneficial to discuss across modern and past timescales (?) such key questions as:
- How variable can rates and patterns of atmosphere-ocean CO_2 exchange be?
- What role does nutrient cycling and "biological pumping" play in these changes?
- What do we know about iron fertilization in the past?
- How will ocean chemistry and marine ecosystems respond to future acidification scenarios?
- Can methane release from ocean sediments perturb the atmosphere and climate?
- Are there non-linearities in the system that could trigger rapid global (climate) changes?

The discussion will aim to reveal which of these questions could be approached by joint activities of SOLAS and PAGES/IMAGES and how this could be done.

What are the challenges for SOLAS Data Integration?

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An important aim of the SOLAS program is the production of global concentration and flux fields for climatically relevant compounds, with an emphasis on early-stage datasets.? The production of such datasets has been prioritised by the SOLAS research community as well as by potential users of such data (especially climate modellers). The SOLAS Project

Integrator (Tom Bell, UEA) has been funded for the next three years to specifically tackle this task. Whilst this position represents a substantial resource, it is important that the work is well co-ordinated within the SOLAS community, duplicating the work of others as little as possible. This discussion session invites the wider SOLAS community to engage with data integration and hopes to answer the following questions:
- What's in it for the individual SOLAS researcher?
- What can and should be achieved within the next three years?
- Are there specific existing questions that, in order to be answered, require data products that could/should be produced from this project?
- What datasets (complete or incomplete) of relevant compounds already exist?

It is important to note that this is effectively a community-lead activity, co-ordinated by the SOLAS Project Integrator; all contributors will be fully acknowledged for their contribution to global flux products (i.e. co-authorship for each relevant dataset and publication(s) arising therefrom).

http://www.bodc.ac.uk/solas_integration

Satellite, Data and Synthesis

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Measurement of parameters relevant to the surface ocean and lower atmosphere by satellite sensors has made enormous progress in recent years. Examples include – besides ocean colour measurements – the determination of trace gases like BrO, NO_2, or glyoxal in the marine atmospheric boundary layer. Also identification of plant and microbial species from their high spectral resolution signatures on land and in the ocean is an emerging technology. In addition aerosol and dust can be determined from space. While several of these technologies are still explorative and being pursued by groups mainly interested in developing the technology it is of great interest to integrate the results of different sensors. For instance fertilisation of the ocean by dust minerals or oxides of nitrogen my enhance or change the algal activity, which in turn may lead to emission of chemical species from the ocean. The aim of the discussion meeting is to start a discussion process, which should lead to more synthesis of satellite sensor data.

CO_2 fluxes in coastal oceans and its role in SOLAS budgeting

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It is increasingly recognized that air-sea CO_2 flux, carbon budgets and carbon cycling mechanisms at continental margins represent an important knowledge gap in global carbon cycle research. Several international, multi-national and national research programs, including SOLAS, CARBOOCEAN, NACP (North American Carbon Program) and OCCC (Ocean Carbon and Climate Change), are addressing this need. A critical research community is now forming to advance this research field, and many recent synthesis results are changing our views of carbon dynamics in the coastal realm. This session invites you to present and discuss the current state of knowledge and seek your input on how to best approach coastal carbon research. Some knowledge gaps that are of interest to initiate the discussion include:

1. How do we upscale local air-sea (air-water) CO_2 flux measurements to regional and global level? (A) Are there sufficient measurements particularly in low latitude and high latitude margins? (B) How can we define various subsystems?
2. How can we quantify the exchange between the coastal ocean and the open ocean on seasonal to interannual timescales?
3. What are the transport, transformation and ultimate fate of terrestrial C and nutrients in various coastal oceans and how do they affect the metabolic balance in these systems?
4. How do we link the pelagic and benthic C cycling to water column and air-sea transfer processes?
5. How will the ocean acidification affect the carbonate system balance in the coastal zone?

SOLAS-CODiM (Comparison of Oceanic Dimethylsulfide Models)

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Dimethylsulfide (DMS) is a volatile biogenic sulfur compound produced in the surface ocean and implicated in the Earth radiative balance and climate. The production of marine DMS is subject to complex physical, biogeochemical and ecological interactions. The refinement of the current global climate models requires a dynamical representation of the DMS emission from the ocean, hence the need for an international workshop on the comparison of oceanic DMS models gathering both experimentalists and modellers. We will report on the preliminary results from the first CODiM workshop held in Brussels in December 2006. We compared both one-dimensional (1D) models against time series at specific ocean sites and three-dimensional (3D) models against global data sets. Although most models were performing reasonably well in general, we found that most of them -whether 1D or 3D -had difficulty reproducing the so-called 'summer paradox", i.e. summer DMS maxima occurring much later than the winter-spring phytoplankton maxima. Model experiments confirm that irradiance is the key environmental driver behind this decoupling of algal biomass and DMS but the models do not agree on the mechanisms involved. The extent of the decoupling remains uncertain but may be more widespread than originally thought. Given the implications for climate models, it is clear that a focus on improving this aspect of process-based DMS cycling models is warranted. All SOLAS participants are invited to come and discuss our preliminary findings.

Future Large-Scale Field Experiments in SOLAS

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To date large-scale field experiments in SOLAS have tended to be concentrated on one or other side of the air-sea interface, e.g. iron fertilisation experiments have been largely concerned with marine processes, whereas lagrangian studies using balloons have had an atmospheric chemistry focus. In this session the aim will be to discuss not only future ocean and atmospheric based experiments but also the possibility of conducting truly coupled atmosphere-ocean biogeochemical field studies. For example, is it possible to study the whole or at least a significant part of the DMS to CCN/clouds cycle in a single study, or do we have to examine the parts of the cycle separately? How can we best simulate at sea dust deposition to the ocean surface and its effects on marine productivity, trace gas production, etc? We may conclude that such coupled studies are unrealistic, in which case the discussion will focus on how to perform studies majorly concentrated on either atmosphere or ocean both better than previously but also to answer questions not yet addressed. It promises to be a lively session, with plenty of room for whacky ideas to be presented and discussed. Who knows, it might even lead to the invention and initiation of the next level of SOLAS field experiments!

Sub micrometer Primary Marine Aerosol emissions: from experiments over parameterisations to large scale models

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Recently, parameterizations have become available for the emission of primary marine sub-micrometer aerosol emission (Martensson et al., 2003, Clarke et al., 2006). These observation-based (field, lab) parameterizations encompass a size range from 10 nm to 10 m. Of particular importance is the nm size range which has been asked for by global scale modelers. The number production in this range is much larger than in the super micrometer range, and given the high hygroscopicity of sea salt particles, this is a very significant source for cloud condensation nuclei (CCN). The first global model estimates that use these source parameterizations (Pierce and Adams, 2006) reveal not only a superior agreement with observed aerosol number size distributions (Heintzenberg et al., 2000), but they suggest also that sea spray dominates the CCN production on most remote oceans, especially in the southern oceans. Even the direct aerosol effect may be dominated by sea spray in remote marine areas: sub-micrometer sea salt can have a more significant radiative forcing than the non-sea salt sulphate (Murphy et al., 1998). New experimental approaches, such as eddy covariance measurements, profiles, and laboratory observations confirm that roughly 50% of the produced particles have a dry diameter smaller than 0.1 micrometer. Furthermore, the effects of sea water temperature is now included in the parameterizations and the effect

of sea spray composition, in particular organic material, is recognized. The use of satellites to provide this information to models is being explored. The aim of the discussion session is to bring experimentalist and modellers together to discuss how to use this information for the assessment of the effect of sea spray aerosol on climate. The experimentalists provide parameterizations of their results, but the question is how these formulations can be optimized for the implementation in large scale models, and how these can benefit from the most recent experimental insights. Experience teaches us that often the parameterizations are too complicated, or that parameters used are not easily accessible in the models. The ultimate goal is to reduce the uncertainty of sea spray direct and indirect climate forcing.

Aerosol iron solubility – in search of some clarity

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The fraction of atmospheric iron inputs that are soluble in seawater is a key parameter in regulating oceanic iron and carbon cycling. This solubility is probably controlled by a variety of factors in the atmosphere (e.g. aerosol source, atmospheric chemical and physical processing) and ocean (e.g. ambient dissolved Fe concentrations, organic Fe complexation). However, there is little consensus as to the dominant mechanisms that control Fe solubility and this may, in part, be due to the wide variety of methods used to determine this parameter. This discussion session will focus on the factors that affect aerosol iron solubility both in the atmosphere and ocean, and how best experimental work can be directed to make progress towards a better understanding of this subject.