Earth Observation for Ocean-Atmosphere Interactions Science: Towards and ESA-SOLAS collaborative action

Summary of the ESA-SOLAS consultation meeting organised in Barcelona the 19th November 2009 during the SOLAS Open Science Conference.

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1. Introduction

Physical and biochemical interactions between oceans and atmosphere involve several key processes governing the Earth system dynamics and its climate. Momentum, hit and gases exchanges and fluxes between the ocean surface and the atmosphere boundary layer influence key components of the Earth system such as the ocean circulation, the Earth radiation budget, the global carbon cycle or biodiversity, among others.

In this context, the observation, quantification and monitoring of the different ocean and atmospheric variables involved in these key processes is of major importance to better understand, characterise and predict their behaviour and their influence in climate and human lives.

The Surface Ocean Lower Atmosphere Study is a major new international initiative to "achieve quantitative understanding of the key biogeochemical-physical interactions and feedbacks between the ocean and the atmosphere, and how this coupled system affects and is affected by climate and environmental change." SOLAS involves over 1500 scientists in 23 countries. Paramount to this effort is to improve mechanistic understanding and obtain global representations of the physical forcing fields. It is envisioned that SOLAS efforts would contribute quantification of some of the basic fluxes in process study.

In the last decade, Earth Observation (EO) technology has been consolidated as a unique global information source for earth science, applications and services. Many satellite instruments measure variables and processes in the ocean (e.g. SST, surface wind stress, surface slicks, sea state, ocean colour radiometry, SSH). Several instruments provide measurements of atmospheric processes (e.g. clouds, NO2 measurements, atmospheric dust and aerosol). In the coming year, the increasing global multi-mission EO observational capacity will provide novel and unprecedented potential to observe, describe and predict the dynamics of key processes governing the ocean-atmosphere interactions and their impacts from local to global scales, hence becoming a major support to SOLAS activities.

In 2008 the European Space Agency (ESA) launched a new program, the STSE (Support To Science Element) dedicated to support scientific activities, develop novel mission concepts, novel products and enhanced applications that may respond directly to the needs of the scientific community. One of the main action lines of the program is dedicated to establish closer links between the agency and the major international scientific groups such as SOLAS.

In November 2009, ESA and the SOLAS International project Office organised a dedicated side event at the SOLAS Open Science Conference organised in Barcelona, to discuss potential areas of common interest. This document provides a summary of the initial discussions and provides a basis for further explore concrete areas for collaboration in the context of the ESA STSE activities.

In this context, the objective of this document is to support a consultation process between ESA and the SOLAS community to perform an assessment of the main areas of research and scientific priorities of SOLAS in terms of novel observations, products and models, where EO and ESA data may contribute. This analysis may be the basis for the definition of ESA activities addressing the SOLAS scientific priorities.

2. Overview of SOLAS Activities and Priorities

The main goal of SOLAS is to achieve quantitative understanding of the key biogeochemical-physical interactions and feedbacks between the ocean and atmosphere, and 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 and ice covered areas.
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.

It is worth noting that the SOLAS Science Plan give a significant importance to the role of EO technology. In particular, it state “Remote sensing data, mainly from satellite sensors, are expected to make a vital contribution to SOLAS. Satellites allow global observation of marine biogeochemical signatures (e.g. ocean colour, trace gases and aerosols), have good temporal coverage, and with 4-5 year missions, provide observations over an extended time period. In particular, satellite observations can put field experiments into a larger temporal and spatial perspective. A need will be to achieve coupling between field data, satellite observation, and models.

SOLAS deals with the following issues or Foci. 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

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

Focus 3: Air-Sea Flux of CO2 and Other Long-Lived Radiatively Active Gases
The air-sea CO2 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 N2O and to some extent CH4. 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.

3. Summary of ESA observational capacities and scientific support program.
Since its early development with the launch of the ERS-1 in 1991, the ESA’s Earth Observation program has paid special attention to the needs of the oceanographic and atmospheric communities. ERS-1 was followed by ERS-2 in 1995 with enhanced capabilities (Global Ozone and improved land surface parameters, see http://www.esa.int/ers). Further

capabilities (ocean colour and atmospheric constituents) followed in 2002 with the launch of ENVISAT (see http://www.esa.int/envisat) – the largest earth observation satellite ever launched. In this context, today, ESA EO missions represent a major information source to estimate several key variables: e.g., ocean surface wind stress/vector, Sea Surface Temperature, Ocean colour, sea ice parameters, surface roughness, Sea Surface Height, derived ocean currents, sea surface slicks, atmospheric gasses amongst other parameters – all of which are relevant to SOLAS.

More recently the ESA Soil Moisture and Ocean Salinity Mission (SMOS) mission was successfully launched on November 2nd 2009. SMOS will provide global maps of soil moisture and ocean salinity for hydrological studies and advance our understanding of the freshwater cycle to improve climate, weather and extreme-event forecasting. The main instrument package is called the Microwave Imaging Radiometer with Aperture Synthesis (MIRAS) which is a new technology based on interferometric measurements of passive microwave emissions in the 1.4GHz waveband. More information can be found at http://www.esa.int/smos.

In the coming future, the Global Monitoring for environment and Security (GMES) Sentinel-1 and Sentinel-3 missions (described at http://www.esa.int/gmes) will provide a sustained operational capability for European ocean earth observation for the next decade. Sentinel-3 provides ocean colour and thermal infrared optical sensors together with a precision synthetic aperture radar altimeter that are all co-located. Sentinel-3 will operate using two polar orbiting spacecraft carrying identical instruments in order to provide the required ocean coverage and is expected to launch in 2013. Sentinel-1, also using two satellites, carries a new C-band synthetic aperture (SAR) with capacities to monitor sea ice zones and the arctic, surveillance of marine environment. Sentinel-1 is expected to launch in late 2012.

In 2008, ESA launched the Support to Science Element (STSE) as a new tool to support scientific activities aimed at:

- Developing of novel mission concepts addressing key observational gaps and scientific needs in preparation for the next generation of European scientific missions.
- Developing of innovative algorithms and products establishing a sound scientific basis for novel applications that may exploit the increasing ESA multi-mission capacity.
- Supporting the Earth System Science Community to maximise the scientific return of ESA missions.
- Reinforcing ESA scientific collaboration with major international scientific programs.

In this context, ESA has establishing a close working collaboration with major international scientific group such as GEWEX, iLEAPS or CliC via the definition of common scientific priorities, the organisation of joint workshops and conferences, the publication of joint papers and scientific reports and the preparation of dedicated projects funded under the STSE to support scientific activities addressing the main scientific priorities of these groups while maximising the scientific return of ESA data.

4. Preliminary areas for further discussion

Based on the preliminary discussion during the meeting Barcelona, the above overview and internal brainstorming in ESA, a preliminary list of priority area are identified tat main represent the basis for further discussion between ESA and SOLAS to identify a number of concrete priority areas for further collaboration via the STSE activities.

In particular, the following topics have been identified:

1. Diurnal variability of ocean surface salinity: study the variability of ocean surface salinity using a combination of in situ (vertical profiling high resolution probes) and EO (SST, SMOS) at a variety of timescales with specific focus on diurnal variability and how this impacts SMOS measurements

2. Economic value of Carbon uptake by Oceans in upwelling zones. Carbon accounting is used widely today to offset anthropogenic emissions. What is the economic capacity of upwelling zones for carbon accounting in EEZ? What is the variability? How could upwelling zones be used in carbon accounting?

3. Extreme heat fluxes in the marginal ice zones. In the marginal ice zones heat fluxes can be extreme when cold dry air flows off the ice and over the ocean. EO data can be used to study such fluxes to investigate their magnitude and variability. Often specific lower atmosphere convection systems develop in these conditions. What is the variability of these systems? What impact do they have on ocean and atmospheric circulations at local and regional scales if any?

4. SST and surface winds. There is an intimate relationship between the surface wind field and SST which can lead to biases in wind speed and SST retrievals from EO sensors. EO data can be used in synergy to investigate the relationship between surface winds and SST together with in situ observations in a variety of ocean and atmospheric situations.

5. Skin temperature deviations and air-sea gas fluxes. It is long recognised that the thermal skin temperature deviation at the air-sea interface has a controlling role in the magnitude and direction of gas fluxes. EO data can be used to investigate further the impact of the skin temperature deviation on a variety of gas fluxes.

7. DMS production and whitecapping: Production of DMS is linked to whitecapping and spray production. This study will use EO data to investigate whitecapping variability and DMS (plus other gasses as fitting) production

8. Accurate and consistent quantification of the ocean carbon fluxes is critically needed in order to better understand the global carbon cycle (e.g. sources and sinks) and support climate change prediction. The idea here is to use a state-of-the-art CCDAS system (Carbon Cycle Data Assimilation System), where the terrestrial carbon fluxes are already constrained by EO data (such as MERIS FAPAR) through a data assimilation system, and combine it with a simple ocean model (including biology) in order to quantify the flux of carbon, in a global and consistent way by constraining the coupled global model with EO data (possibly form the same sensor like MERIS, providing FAPAR on land and Chlorophyll on the ocean).

9. Accurate quantification of phytoplankton chlorophyll-a fluorescence (based on MERIS) for enhancing modelling of ocean productivity, characterizing physiological information in the global oceans, improving ocean photosynthesis estimates, and resolving climate-phytoplankton interactions.

5. Conclusions

On the basis of these and other potential priority areas a dedicated ESA-SOLAS scientific consultation workshop will be organised early in 2010 in order to further discuss these and other potential topics with the SOLAS community in order to consolidate a number of priority areas of common interest for ESA and SOLAS.

In this context, the ultimate objective of this workshop would be the preparation of a Scientific Requirement Document describing the major scientific needs and priorities of the SOLAS communities in terms of novel observations, products, models and scientific results where ESA missions and EO data may contribute. This document will provide a basis for ESA to prepare a potential ESA-SOLAS STSE dedicated project in 2010.