BIOLOGICAL EFFECT OF ON AIR-SEA CO2 FLUXES AS MEASURED BY EDDY COVARIANCE

REPORT ON THE SHORT TERM SCIENTIFIC MISSION (STSM)
COST-STSM-735

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Motivation and background

Anthropogenic emissions of greenhouse gas have increased significantly since the industrial revolution due to the burning of fossil fuels, the production of cement and changes in land use. Nowadays the emission of anthropogenic carbon dioxide (CO_2) is of 9.1 PgC yr^{-1} (Canadell et al., 2007) what half of it is accumulated in the atmosphere (Le Quere et al, 2009). Thus, the CO_2 concentration has increased in the atmosphere from 270 ppm found in the pre-industrial level up to the present 384 ppm (Solomon et al., 2007).

The world’s oceans particularly play an important role as a sink of CO_2 with approximate estimates of 2.2 PgC yr^{-1} (Sabine et al., 2004). There are however large uncertainties and gaps in the magnitude and the temporal and spatial patterns of the air-sea exchange of CO_2 (McGillis *et al*, 2001). In a changing climate system, an understanding of air-sea CO_2 fluxes is vital for predicting the behaviour of the global carbon cycle, and the climate feedbacks associated with it.

In order to improve our understanding of the ocean CO_2 uptake, there is an international effort to carry out extensive *in situ* measurements at oceanic basin scales using different equipments and platforms. Most of the estimations of air-sea CO_2 fluxes are usually computed from underway measurements of CO_2 partial pressure gradient between atmosphere and ocean. This implies that substantial errors in flux computations are incurred due to the uncertainties of the *k*-wind. However there is a technique as the Eddy Covariance method (EC) recently used on board research vessels for directly measuring the air-sea CO_2 flux and resolving gas transfer velocity variability on short time scales. This technique estimates the air-sea gas flux by correlating fluctuations in gas concentration with those of vertical wind speed over a point in the surface boundary layer (Donelan and Wanninkhof, 2002). However these measurements are generally restricted to a few locations with large CO_2 partial pressure gradient, as the average flux is too weak to be confidently detected by current gas analyzers from the noise caused by instrumentation, heat and water vapour fluxes, and platform motion.

The School of Physics of National University of Ireland in Galway has a strong expertise of interactions within air-sea interface using different autonomous equipments, mainly, in the meteorological station of Mace Head (Ireland). The Prof. Brian Ward who has recently incorporated to the School of Physics has given impetus to the study of air-water CO_2 fluxes with an ambitious project. To quantify CO_2 fluxes and its relationship to wind speed and biological activity, different devices were installed on board of research vessel R/V Celtic Explorer. Measurements of CO_2 fluxes using EC method were simultaneously recorded with air-sea CO_2 gradient observations from two underway systems, namely, PSI CO2-Pro and the model 8050 of General Oceanics. The EC instrumentation array that is installed on a 10 m mast on the bow consists of a sonic anemometer for measuring the vertical wind component, two open path Li-Cor 7500 infrared gas analyzers for measuring CO_2 concentration, mean meteorological sensors (wind, temperature, humidity, and pressure), motion sensor, GPS, and a camera for recording images of sea state. These micro-meteorological methods that are able to carry out high-frequency, long-term and large scale measurements of air-water CO_2 fluxes has been permanently installed on the ship gathering continuous automated recordings for approximately 18 months usually over the Irish continental shelf (Figure 1).

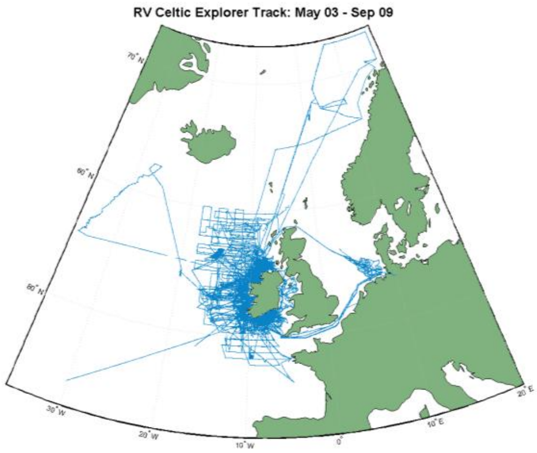

Figure 1. Cruise track of the RV Celtic Explorer between May 03 and September 09.

My research that is developed in the Marine Research Institute – CSIC of Vigo is focused on air-sea CO_2 exchange and associated biogeochemical processes, mainly in ocean waters of the North Atlantic Ocean. These investigations are lead by Fiz F. Pérez and Aida F. Pérez that are highly motivated towards incorporating new instruments for measuring CO_2 in the Spanish research vessels. The purpose of this STSM was to visit the laboratory of Prof. Brian Ward (National University of Ireland in Galway) who is studying CO_2 dynamics in the North Atlantic Ocean from different instruments including EC method.

In order to receive training in the using of EC system, I have spent 3 months (from 8th March to 4th June 2010) within the group of Dr Brian Ward at the National University of Ireland in Galway.

Summary of activities

Under the supervision of Prof. Brian Ward and the guidance of Dr. Marc Defossez and Noel Fitzpatrick, I have performed several tasks for becoming familiarised with the theory and practice of the EC technique.

During my internship in Galway, the EC system was installed on board of Celtic Explorer on 17th March. This task with the reading of the technical and scientific documentation about the EC method during the first weeks enabled me to identify and gain insight into the operation of each of the principal components of the EC system.

Next, I studied the different steps needed to process the EC data that are being continuously recorded on board the R/V Celtic Explorer, and their progress. This effort let me gain experience with the different functions and troubleshooting aspects of the data processing for the conditioning of the data, and its conversion into Matlab format. After that, the motion of the ship is corrected using cut-off frequencies or the position vector of the motion package before estimating the flux calculations.

The set-up of the system has relatively strong logistics constrain and some issues raised during field work. Between the 11th and 16th of May 2010, while the R/V Celtic Explorer was in port in Galway, a new CO_2 analyzer was installed on the mast. This model, the Licor LI-7200, has just been released and represents a significant redesign of the EC gas analyzer. It is anticipated that this new system will provide a greater signal to noise ratio, facilitating more sensitive observations.

During the subsequent cruise developed on the R/V Celtic Explorer on the Irish continental shelf from the 16th to the 22nd of May, the new analyzer was run in tangent with the pre-existing instrumentation, and adjustments were made to its operational software and the logging of its data. The system was set up to run automatically, and at the end of the cruise, was left to continue operating and recording by itself. The data obtained during this cruise, and from continuous measurements, will be used to compare the performance of the new and old analyzers, and will provide more observations for air-sea CO_2 flux calculation.

Moreover the model 8050 of General Oceanics that is widely used by the scientific community was also installed prior to the cruise in the wet laboratory of the ship. Even the plumbing of the equipment and the connection of the different sensors were done and reviewed, the adjusting could not be completed during the cruise. All these activities allowed me to develop the sufficient competence for the unsupervised operation of the EC system and gave me the opportunity to participate in the installation of an underway-measuring systemas model 8050 of General Oceanics.

The second general objective of the STMS was to transfer the EC technology to the Marine Research Institute – CSIC of Vigo. A detailed list of the full specifications of the parts of the EC system and the relevant suppliers was assembled during my stay in Galway. Moreover I engaged in fruitful discussion with Dr. Ward about the design and construction of an EC system with the technology currently available.

Outcomes

This STSM allowed me to develop a detailed knowledge of the methodology behind the measurement of air-sea CO_2 fluxes using EC technique. Furthermore I could take part to the preparation and the deployment of the apparatus for measurement of CO_2 fluxes by eddy-correlation. I have also been involved in data processing and analysis. The training covered all aspects of the method and troubleshooting and the components and parameters to be controlled for getting these measurements. After this period, my intention is transfer this expertise to Spanish research vessels from the next project announcements involving further collaboration with Prof. Brian Ward.

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