P1.3 CO2 FLUX MEASUREMENTS DURING SEASAW

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1. INTRODUCTION

Determining the rate of exchange of trace gases across the air-sea interface is of paramount importance to climate studies. A large proportion of anthropogenic CO_2 is absorbed from the atmosphere by the oceans, of which approximately 60% is absorbed by the Atlantic Ocean (Takahashi et al., 1997). This net uptake is the result of a complex pattern of spatially and temporally varying source and sink regions.

Global carbon cycle models rely on CO_2 gas transfer velocity parameterisations to obtain global estimates of the oceans' CO_2 uptake. The parameterisations show an increase in CO_2 gas transfer velocities with increasing wind speed (e.g. McGillis et al. 2001b), but show a scatter between studies of at least a factor of two. Very few direct measurements of CO_2 gas transfer velocities have been made at wind speeds exceeding 10ms^{-1} and as a result the parameterisations at high wind speeds diverge substantially and become even more uncertain.

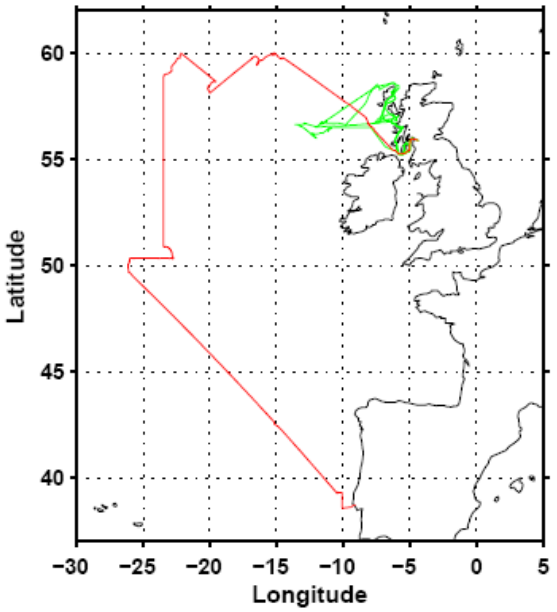

Figure 1: Cruise tracks: D313 (green) and D317 (red).

The Sea Spray, Gas Flux and Whitecap (SEASAW) study is a part of the international Surface Ocean Lower Atmosphere Study (SOLAS); its aim was to make measurements of CO_2 and sea spray aerosol fluxes under high wind speeds and improve the flux parameterizations. Direct CO_2 flux measurements were made via the eddy covariance technique during two research cruises undertaken in the North Atlantic aboard the RRS Discovery (Brooks et al. 2007a): November 7 to December 2, 2006 (cruise D313) and March 21 to April 12, 2007 (cruise D317). Figure 1 shows the cruise tracks during each cruise. Measurements were obtained under mean 10-m wind speeds of up to 23 m s^{-1} during D313 and 18 m s^{-1} during D317.

2. BACKGROUND

Air-sea CO_2 fluxes are driven by a potential air-sea difference in the partial pressure of CO_2 (ΔpCO_2), where positive ΔpCO_2 values result in the transfer of CO_2 into the atmosphere and vice versa; the bulk air-sea CO_2 flux can be defined as follows (McGillis et al. 2001b):

$$F_{CO2} = s_{CO2}\, k_{CO2}\, \Delta pCO_2$$

where s is the solubility of CO_2 and k is the CO_2 gas transfer velocity. The dependence of the transfer velocity of CO_2 across the air sea boundary at a given ΔpCO_2 in terms of sea state variables is not fully understood. Relationships between gas transfer velocity and wind speed, wave height, sea surface temperature and whitecap fraction have all been explored (e.g. Fairall et al. 2000). Wind speed is found to be the first order driving force for CO_2 fluxes and has been the only factor that has been extensively studied until recently. Although the resulting relationships diverge at higher wind speed values (McGillis et al. 2001b), and differ by at least a factor of two, climate models incorporating the global carbon cycle often use wind speed as the sole factor to determine the CO_2 gas transfer velocity (e.g. Takahashi et al. 2002).

The most direct method of determining CO_2 fluxes, from which the transfer velocity is then derived, is eddy covariance. These are challenging measurements to make from a mobile platform such as a ship, and there are few data sets available to date. Measurements incorporated into the derivation of CO_2 gas transfer velocities include the high frequency atmospheric CO_2 concentration, three dimensional wind field and ship

motion, and mean ΔpCO_2 derived from the atmospheric and oceanic pCO_2 measurements.

3. INSTRUMENTATION

Two eddy covariance systems were installed on the foremast of the RRS Discovery (Figure 2), one from Leeds, the other from the National Oceanographic Centre (NOC), Southampton. Both utilized a LiCOR 7500 open path gas analyzer to measure the turbulent fluctuations of the atmospheric concentration of CO_2. These were collocated with Gill R3A sonic anemometers and motion sensing packages to determine the attitude and acceleration of the ship, allowing the ship motion to be determined and removed from the measured wind components (see Brooks et al 2007b for more details). The Leeds instrumentation was positioned at the top of the foremast at a height of 21 m above the surface; the NOC instruments were mounted at approximately 18 m above the surface, at either side of the foremast platform. Air and water pCO_2 measurements were made by the UEA COCO instrument during D313, and by the PML/CASIX pCO2 instrument during D317. Atmospheric pCO_2 was measured using a LICOR 6262. The oceanic pCO_2 was measured by bringing the seawater CO_2 into equilibrium with the air CO_2 within a closed medium: this procedure required a sampling interval of 30 minutes.

SUMMARY

Processing of the data from both cruises is underway. Results to be presented will include the derived CO_2 transfer velocities for a range of wind speeds ranging up to 18 m s^{-1} during D317 and 23 m s^{-1} during D313: in both cases the results contribute to the scarce measurements of gas transfer velocities at high wind speeds. This will allow for a comparison between the newly obtained results and previous CO_2 gas transfer velocity parameterisations (e.g. McGillis et al. 2001b). CO_2 gas transfer velocities will also be compared to the wave state and the whitecap fraction (Brooks et al. 2007a).

An assessment of the synoptic implications of the newly derived gas transfer velocity trend at high wind speeds will also be made: the results will include an inter-comparison between the observed ΔpCO_2 and CO_2 fluxes, the globally modelled CO_2 fluxes and the climatological values of ΔpCO_2,

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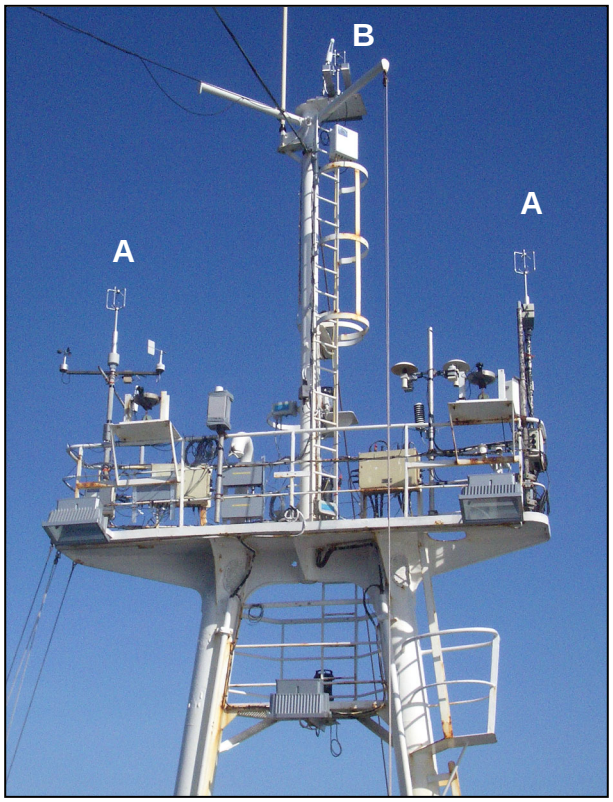

Figure 2. Foremast of the RRS Discovery from behind. The NOC Autoflux sonic anemometers can be seen at either side of the platform (A), the Leeds sonic (B) is just visible with a LiCOR-7500 gas analyzer situated just behind it on the top of the mast.