AIRCRAFT-BASED OBSERVATIONS OF AIR-SEA FLUXES DURING THE GREENLAND FLOW DISTORTION EXPERIMENT

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1. INTRODUCTION

Fluxes of momentum, heat and moisture between the ocean and the atmosphere are a necessary for condition for deep ocean convection which overturns the thermohaline circulation. Thus air-sea fluxes are important for the climate system. The conditions for deep ocean convection are only satisfied in a few region of the oceans, with the Irminger Sea being recently suggested as a convection site (Marshall and Schott, 1999). During the Greenland flow distortion experiment (GFDex), an aircraft based field campaign in 2007, air-sea fluxes of momentum, heat and moisture were obtained over Denmark Strait and the Irminger Sea in high wind, cold air outbreak conditions. Data from over 100 turbulence runs are presented here, each of 2 minutes length.

2. THE GREENLAND FLOW DISTORTION EXPERIMENT

GFDex is an international project investigating the role of Greenland in defining the structure and predictability of both local and downstream weather systems (Renfrew et al. 2008). The field campaign was primarily aircraft based, utilising the specially instrumented Facility for Airborne Atmospheric Measurements (FAAM) BAE146 aircraft. Six of the twelve GFDex missions included low-level flight legs at „minimum save altitude", approximately 30-50 m above the sea, see Fig. 1. High freqency wind, temperature and humidity data were used to calculate eddy covariance wind stress, sensible and latent heat fluxes. Furthermore, the exchange coefficients for momentum, heat and moisture were calculated.
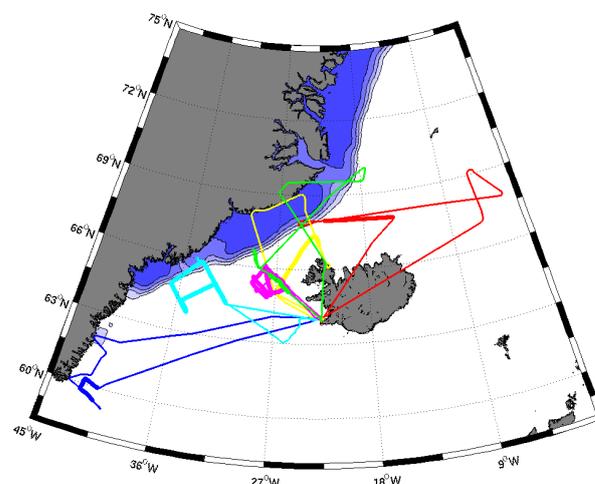
Figure 1: Flight tracks of the GFDex missions with low-level flight legs. The flight tracks are shown with thin lines and the low-level flight legs with bold lines. The sea ice concentration on 5 March 2007 is shown in shading, contour interval 0.2.

3. FLUX MEASUREMENTS

The low-level flight legs were divided into 2 min flux runs, ~12 km, in order for each run to sample homogeneous data but a multiple of turbulent eddies. The flux runs where quality checked in a similar manner as in French et al.

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(2007). In total there were 145 flux runs, thereof 131 over open water. Of those 131 flux runs 120 were accepted for wind stress calculations, 109 for sensible heat and 102 for latent heat flux calculations.

Figure 2 shows the eddy covariance estimates of wind stress, sensible and latent heat fluxes. The 10-m neutral wind, U_{10N}, speed ranges from 5-25 ms^{-1} with majority of the data within the 15-19 ms^{-1} range. The wind stress over open water increases roughly as U_{10N}^2 resulting in a large range of wind stresses from 0.2 to 1.9 Nm^{-2}. The senble and latent heat fluxes vary linearly with differences in temperature and humidity between the atmosphere and the surface. The heat fluxes range from 50 to 300 Wm^{-2}. The sensible and latent heat flux vary in a similar manner resulting in total heat loss from the ocean to the atmosphere of 100 to 600 Wm^{-2}. There are only a few data points in regions where the ocean is partly or fully ice covered. There data points are characterised by low to moderate wind speed, small air-sea gradients in temperature and humidity and thus low air-sea fluxes.

4. EXCHANGE COEFFICIENTS

The 10-m neutral exchange coefficients for each flux run are shown in Fig. 3. It is clear that the majority of our data lies in a relatively narrow range of U_{10N}, and it encompasses quite a large range of exchange coefficients. However, the expected and measured variability of the GFDex flux data are in agreement. 80% of the flux runs have U_{10N} in the range 14-19 ms^{-1}. The data are binned into 1 ms^{-1} bins for wind speeds where at least 10 data points are available.

The 10-m neutral mean drag coefficients show little variation with wind speed, the bin-mean drag coefficient being $C_{DN}= 2.04 \times 10^{-3}$. The bin-mean 10-m neutral heat exchange coefficients vary with wind speed, the mean value being $C_{HN}= 1.63 \times 10^{-3}$. Neither the lack of the expected variation in C_{DN} nor the variation in C_{HN} are particularly signfcant due the the limited U_{10N} range. The bin-mean moisture coefficients are almost constant, the mean value being $C_{EN}= 1.57 \times 10^{-3}$. The
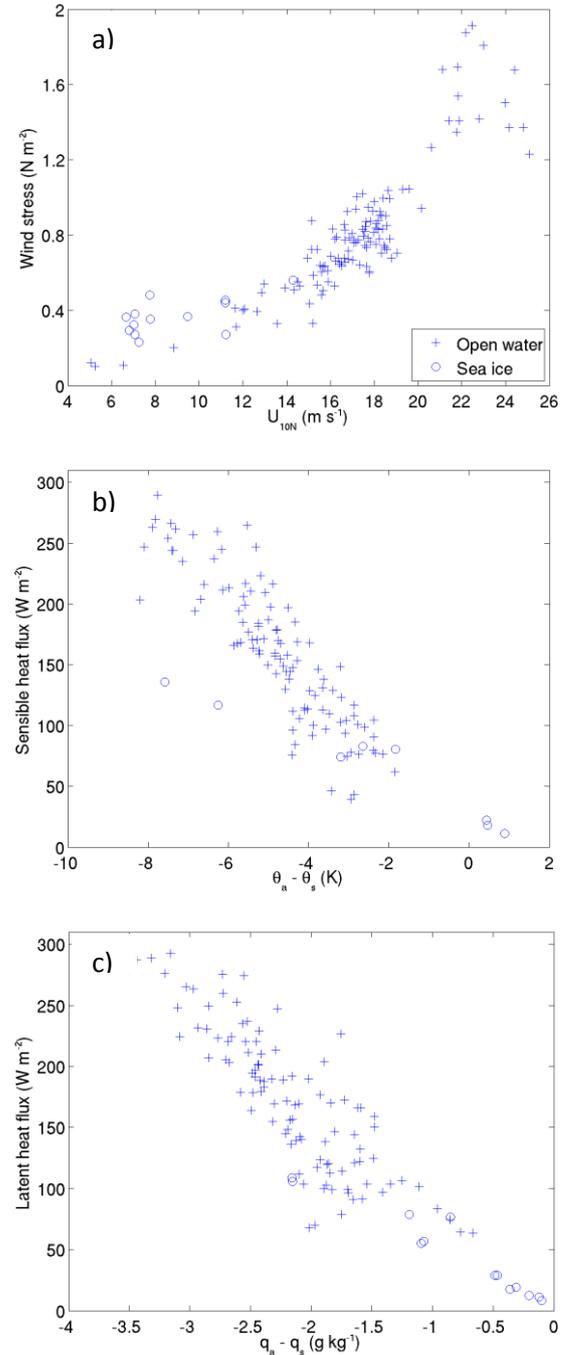

Figure 2: (a) Wind stress (Nm^{-2}) as a function of U_{10N} (ms^{-1}), (b) sensible heat flux (Wm^{-2}) as a function of air-sea potential temperature difference (K) and (c) latent heat flux as a function of air-sea humidity difference (gkg^{-1}). Flux runs over open water are represented by crosses and those affected by sea ice by circles.

exchange coefficients are at the upper end of reported coefficients but withing the variability the previously reported range.
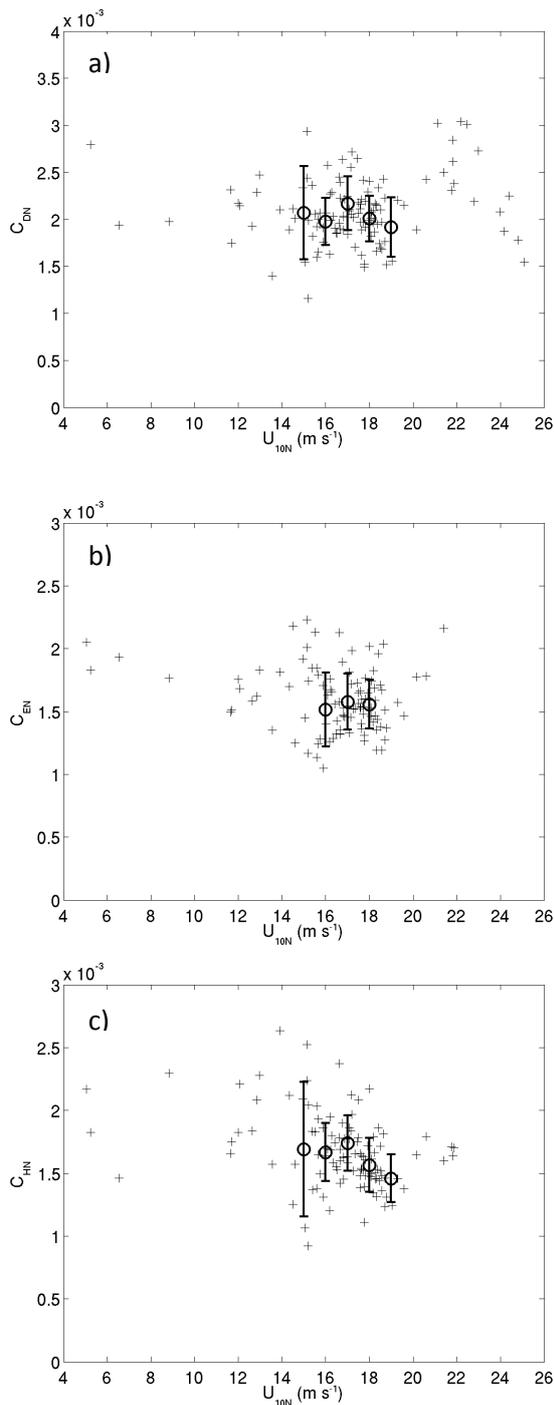
Figure 3: 10-m neutral exchange coefficients over open water for (a) momentum, (b) sensible heat and (c) latent heat as functions of the 10-m neutral wind speed (ms^{-1}). The 1-ms^{-1} bin-mean values are shown for circles and the error bars show one standard deviation. Only bins with at least 10 data points are shown.

5. CONCLUSIONS

One of the goals of GFDex was to obtain estimates of the air-sea fluxes of momentum, heat and moisture over Denmark Strait and the Irminger Sea. These fluxes may be of great importance for the ocean below as it has been suggested that the thermohaline circulation overturns in the region. During GFDex direct estimates of air-sea fluxes were obtained. The measured fluxes are large, e.g. the total heat loss from the ocean to the atmosphere varied from 50-600 Wm^{-2}. At its maximum, this total heat flux is about double the measured downward clear-sky short wave radiation. The exchange coefficients are at the upper end of reported values. This may not be surprising when noted that the GFDex observations are direct aircraft observations at high latitudes, in high wind speed, cold air outbreak conditions, i.e. extreme situations. The GFDex air-sea turbulent flux data set is an important addition to the small number of data sets obtained in moderate to high wind speed conditions. The flux measurements are described in more details in Petersen and Renfrew (2008).

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