High Wind Gas Exchange Study (HiWinGS)

- Primary goal: reducing uncertainty in rate of air-sea gas transfer rate. Uncertainty > 100% at 15 m/s. Grey shading is range of results, line colour indicates measurement method.
- US Research Vessel (RV) Knorr equipped with turbulent flux and sea state (11 m spar buoy, Waverider buoy, 2 whitecap cameras) instrumentation (Photo 1).
- Measurements made during several storm systems in the North Atlantic in Autumn, 2013 (Figure 2).
- Max 30-minute average 10 m neutral wind speed 26.3 m.s$^{-1}$, significant wave height 10.7 m (Figure 3).
- Direct eddy covariance (EC) momentum flux measurements show expected open ocean relationship with wind speed (Figure 4).

Whitecaps

- Gas and aerosol fluxes have a physical relationship with surface whitecaps via bubble-mediated transfer and sea spray generation.
- Whitecap images obtained throughout HiWinGS using two digital cameras (port and starboard facing) operating at 0.2 Hz. Whitecap fraction obtained using an automated method, plus manual quality control (Figure 5).
- Preliminary HiWinGS results have similar dependence on wind speed, though lower absolute values, than widely used existing parameterisations (Figure 6).

Aerosol flux

- Direct EC aerosol flux measurements made using a Compact Lightweight Aerosol Spectrometer Probe (CLASP; Photo 2).
- CLASP counts aerosol number in 16 size bins (0.17μm – 7.5μm). Sub-micron measurements show clear dependence on wind speed and relatively little scatter (Figure 7). Larger sizes not likely to be usable due to experimental setup on HiWinGS.
- Sea spray source fluxes are similar values to published functions (Figure 8).
- Total aerosol flux was compared with wave roughness Reynolds number (Zhao and Toba, 2001; combines friction velocity, significant wave height and seawater viscosity).
- HiWinGS total aerosol flux has similar relationship with $R$, $H$, $H_s$ to one obtained from an earlier experiment using CLASP EC measurements (Norris et al., 2013; GRL). Sea surface temperature in the two experiments was similar (~8-12°C).

Photo 1. RV Knorr in heavy seas near Greenland. Flux instrumentation is on the bow lattice mast.

Figure 1. Wind speed parameterisations of air-sea gas transfer rate. Uncertainty > 100% at 15 m/s. Grey shading is range of results, line colour indicates measurement method.

Figure 2. Cruise track (~ North to South) and (QCed) flux measurement locations during HiWinGS. Colour indicates 30-min 10m neutral wind speed.

Figure 3. Histograms of 30-min 10m neutral wind speed (top) and significant wave height (Riegl laser range finder; bottom). Red bars are measurements passing flux QC.

Figure 4. HiWinGS 30-min 10m neutral drag coefficients (top). A CFD-derived correction is used to adjust flow height and mean relative speed to correct for ship flow distortion. Wind direction limits determined using drag anomalies from bow-on measurements (bottom).

Figure 5. HiWinGS whitecap image showing determination of fractional coverage via threshold method of Callaghan et al. (2008).

Figure 6. HiWinGS whitecap fraction derived from port (# images 79,178) and starboard (# images 14,130) facing cameras.

Figure 8. HiWinGS sea spray source fluxes adjusted to relative humidity of 80%, for wind speeds 17 and 20 m/s. Error bars are σ. Published sea spray source functions valid at the selected wind speed are also shown.

Figure 9. HiWinGS total aerosol flux measurements plotted against $R$, $H$, $H_s$. Dotted lines are 95% confidence of the fit. Red line is fit obtained from CLASP during the SEASAW field campaign (Norris et al., 2013; GRL).