Air-Sea Aerosol Flux and Sea State Measurements During HiWinGS

John Prytherch, Ian Brooks, Sarah Norris, Matt Amison, Amy Prytherch, Josh Talib, Byron Blomquist, Ludovic Bariteau, Helen Czerski, Chris Fairall, Jeff Hare, Adrian-Victor Matei, Robin Pascal, Margaret Yelland

University of Leeds, School of Earth and Environment, Leeds, UK

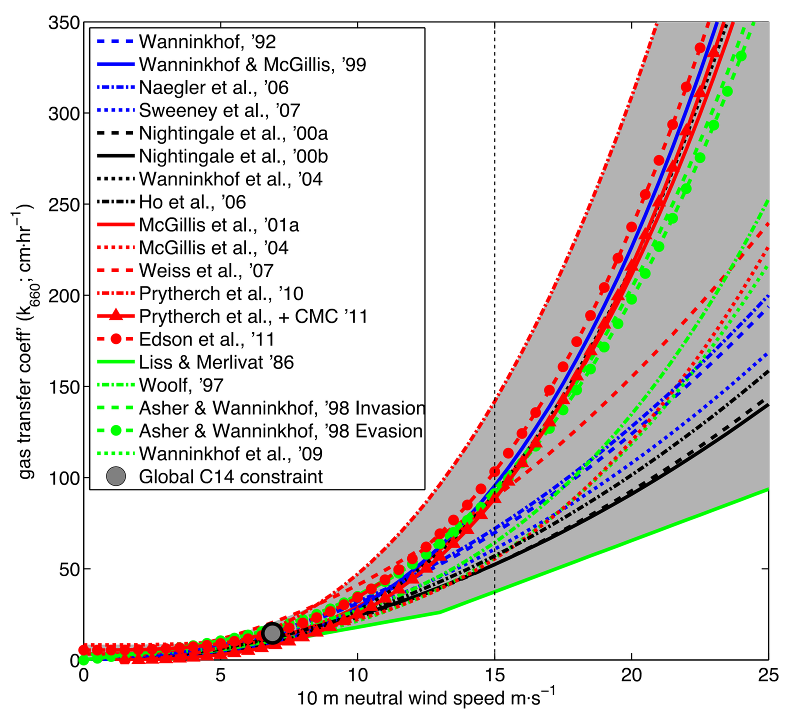


Figure 1. Wind speed parameterisations of air-sea gas transfer rate. Uncertainty > 100% at 15 m/s. Grey shading is range of results, line colour indicates measurement method.

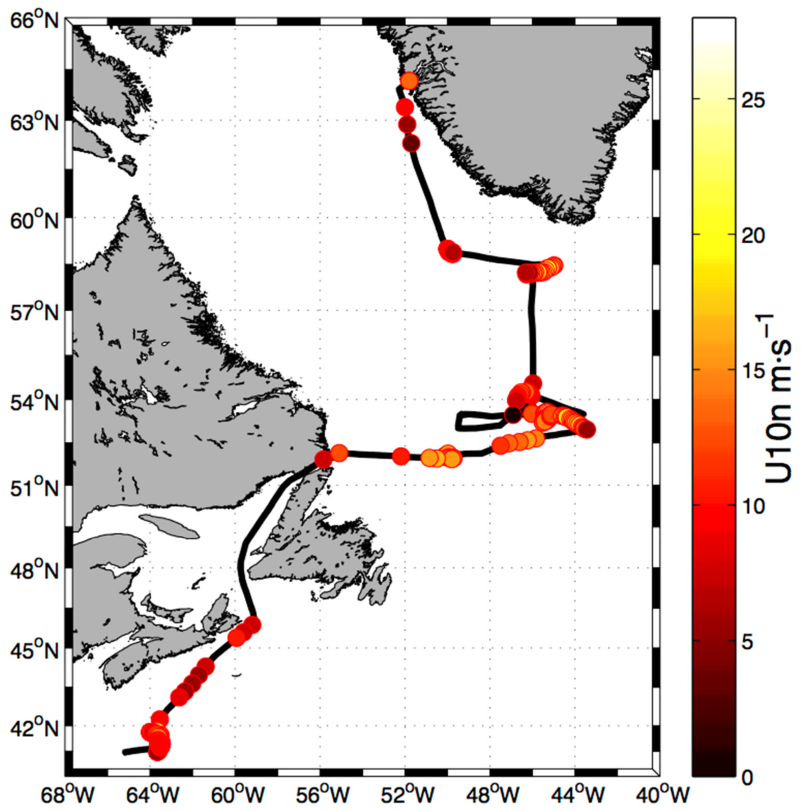


Figure 2. Cruise track (~ North to South) and (QCed) flux measurement locations during HiWinGS. Colour indicates 30-min 10m neutral wind speed.

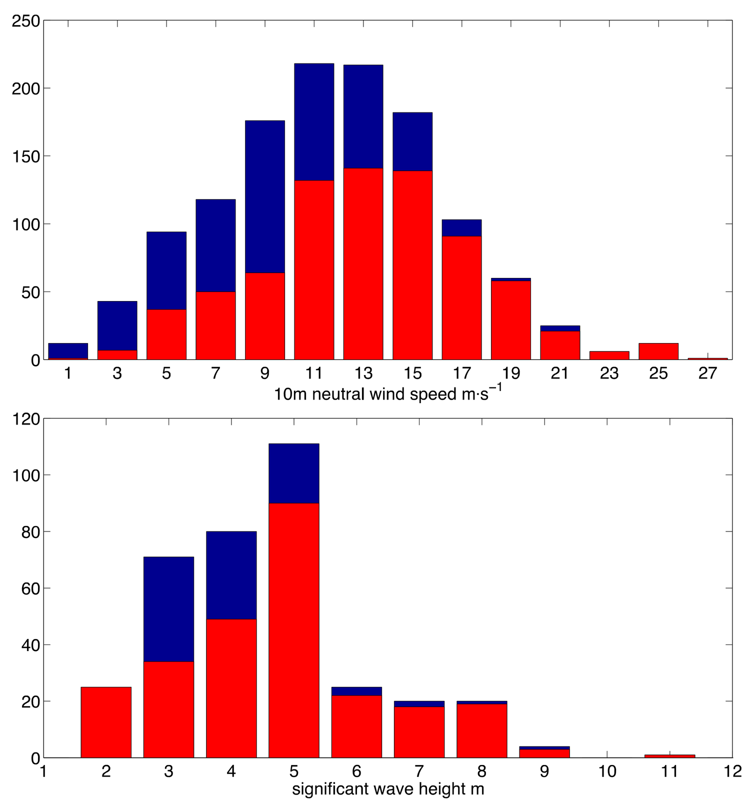


Figure 3. Histograms of 30-min 10m neutral wind speed (top) and significant wave height (Riegl laser range finder; bottom). Red bars are measurements passing flux QC.

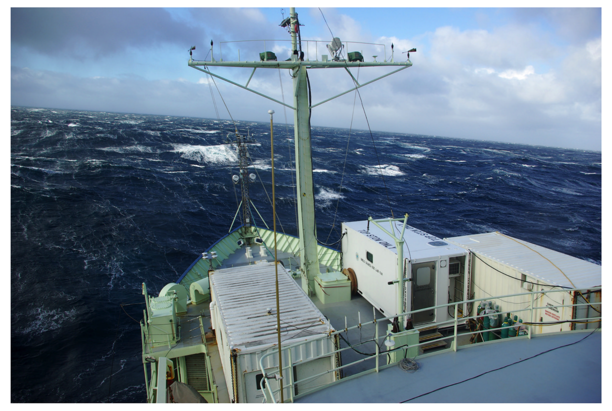


Photo 1. RV Knorr in heavy seas near Greenland. Flux instrumentation is on the bow lattice mast.

High Wind Gas Exchange Study (HiWinGS)

- Primary goal: reducing uncertainty in rate of air-sea gas transfer (Figure 1). Do forcings other than wind speed explain range of results?
- 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).

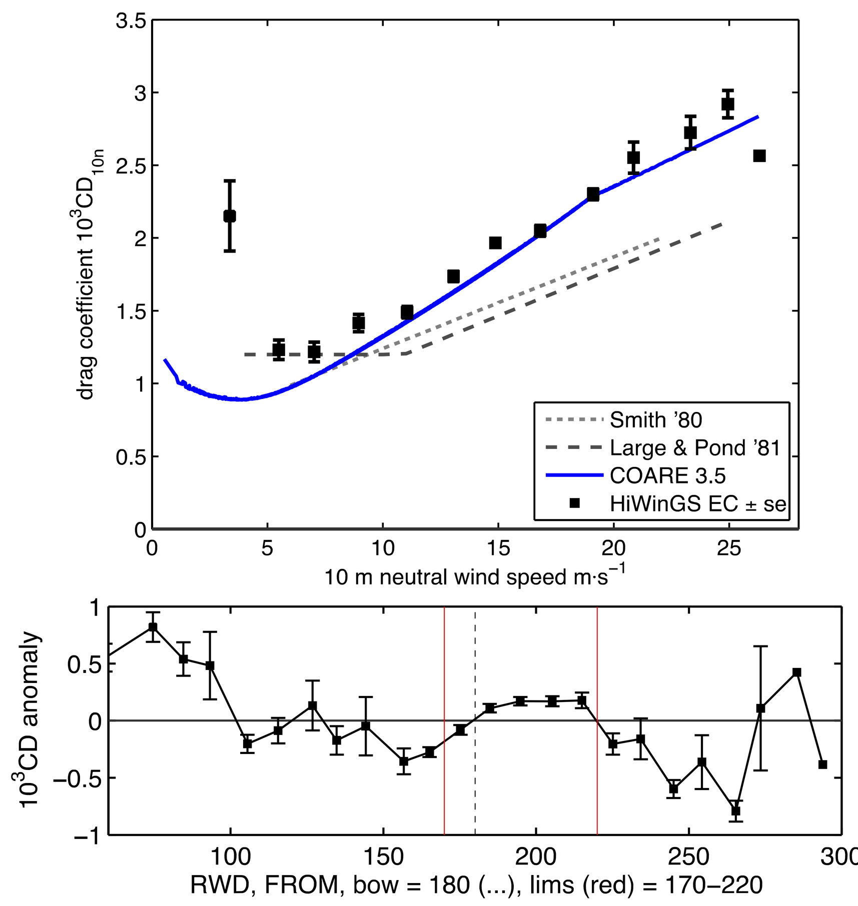


Figure 4. HiWinGS 30-min 10m neutral drag coefficients (top). A CFD-derived correction is used to adjust flow height and mean relative speed to correct for ship flow distortion. Wind direction limits determined using drag anomalies from bow-on measurements (bottom).

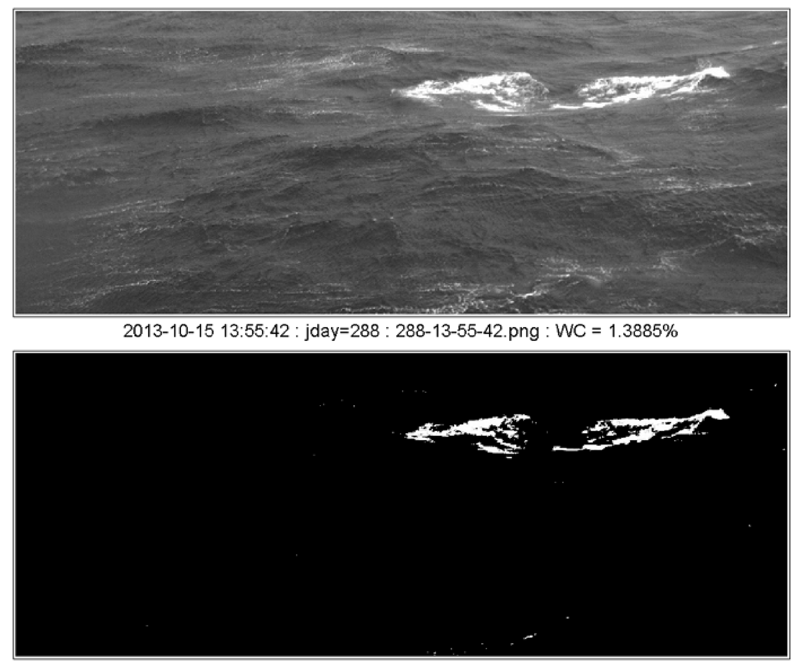


Figure 5. HiWinGS whitecap images showing determination of fractional coverage via threshold method of Callaghan et al. (2008).

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).

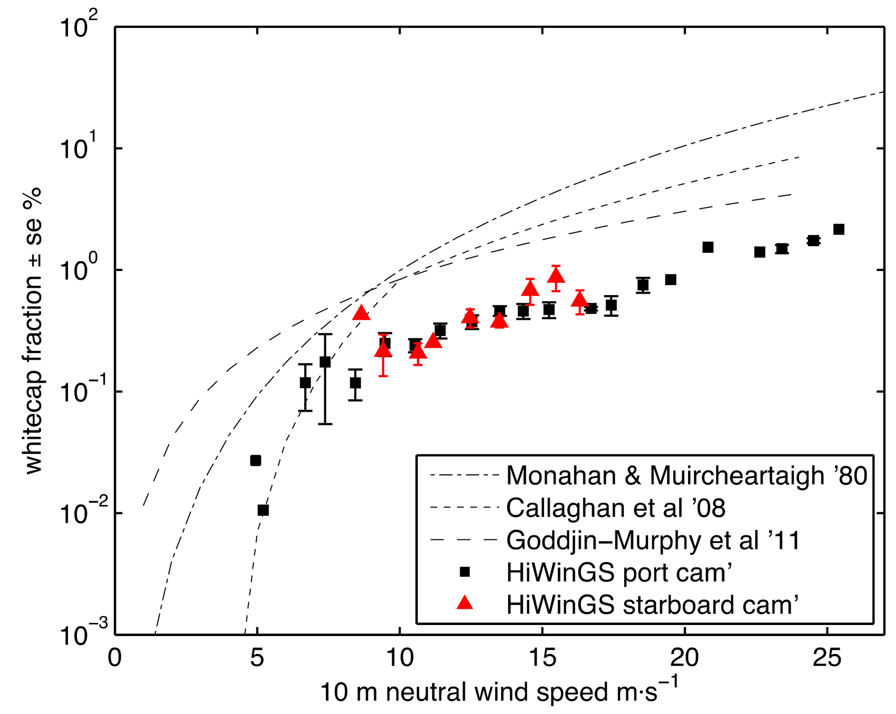


Figure 6. HiWinGS whitecap fraction derived from port (# images 79,178) and starboard (# images 14,130) facing cameras

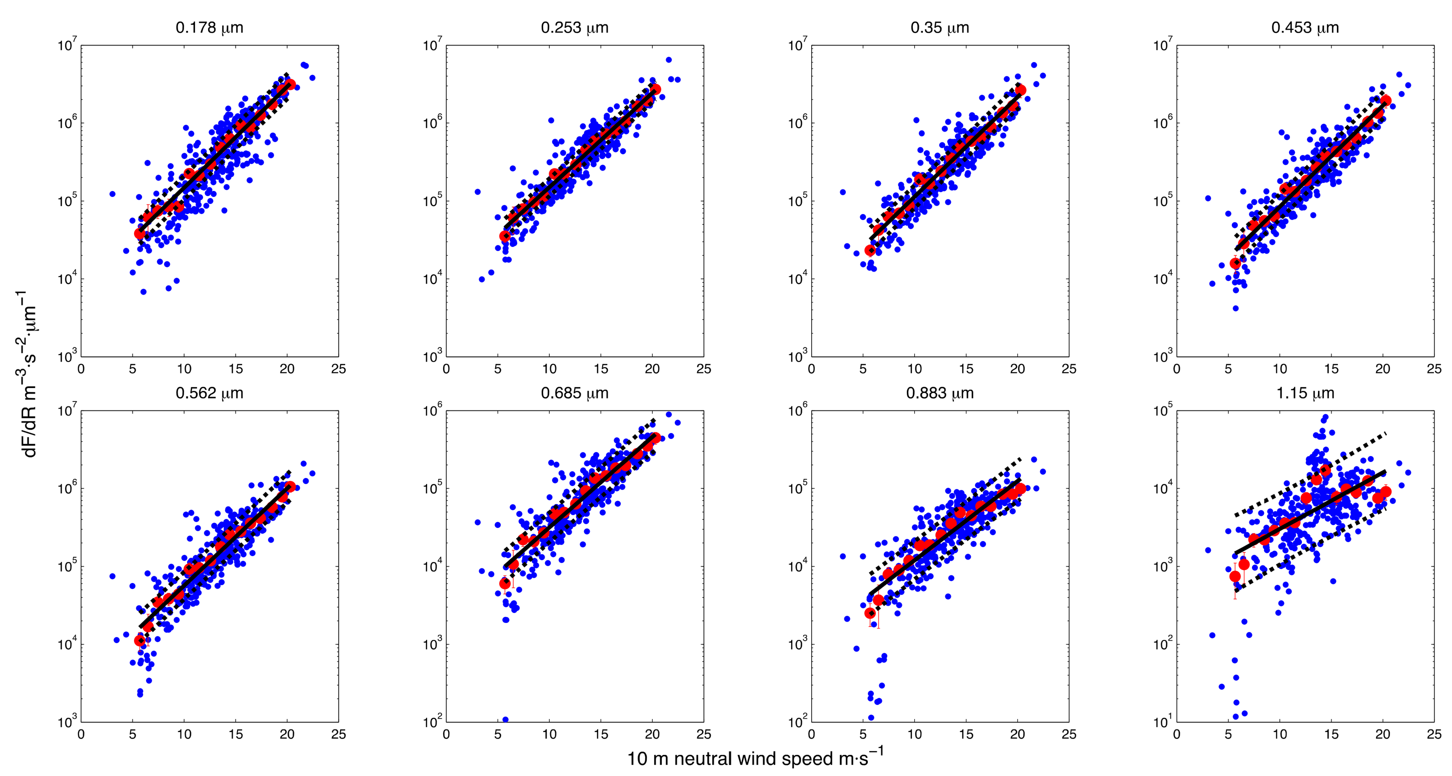


Figure 7. EC aerosol flux measurements from HiWinGS adjusted to relative humidity of 80%. Results for each size channel plotted separately. Black line shows best fit, dashed lines are 95% confidence for the fit. Red dots are wind speed-binned fluxes.

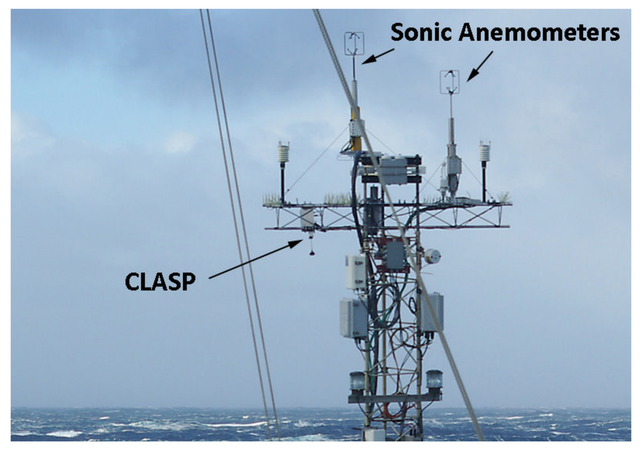
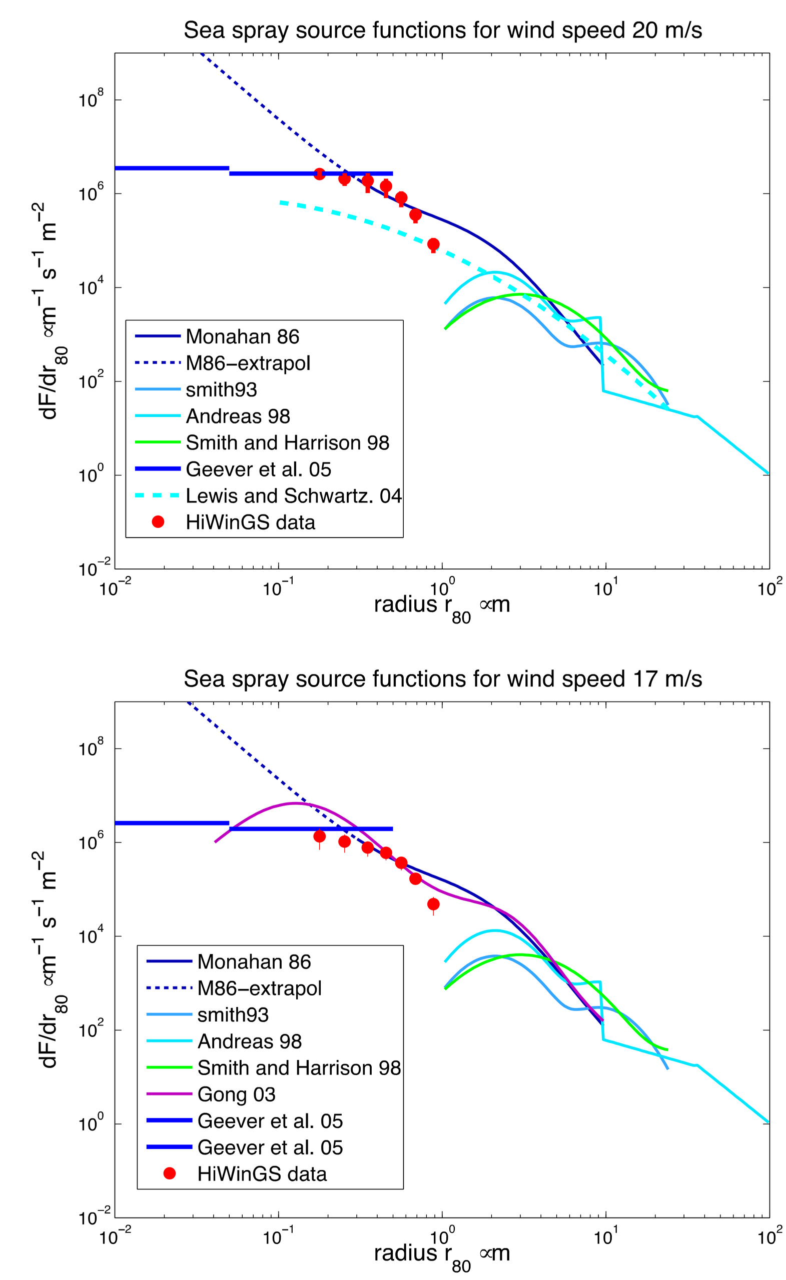


Photo 2. Sonic anemometer and CLASP turbulent flux instrumentation on RV Knorr's foremast.



Aerosol flux

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.

- 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).

$$R\_H = \frac{u^* Hs}{\nu}$$

- HiWinGS total aerosol flux has similar relationship with *R_H* 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).

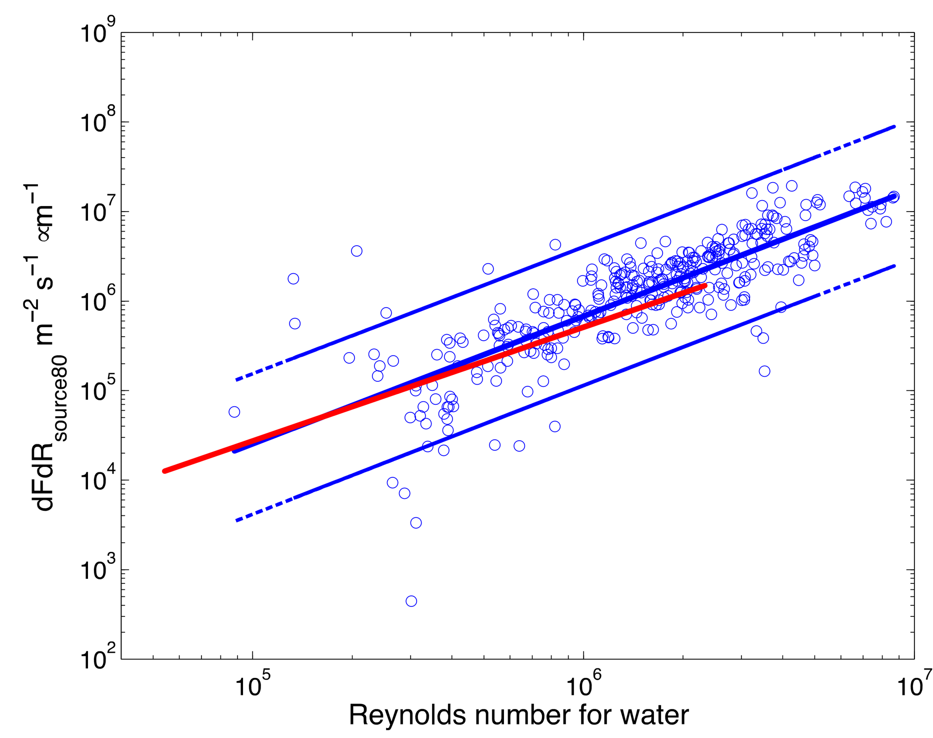
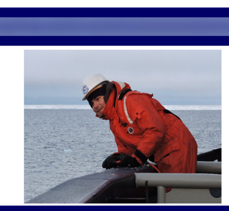


Figure 9. HiWinGS total aerosol flux measurements plotted against *R_H*. Blue line is best fit, dotted lines are 95% confidence of the fit. Red line is fit obtained from CLASP during the SEASAW field campaign (Norris et al., 2013; GRL).

earjpr@leeds.ac.uk
Twitter: @DrPrytherch



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