Supplement of

Uncertainties in eddy covariance air-sea CO_2 flux measurements and implications for gas transfer velocity parameterisations

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Supplement Material

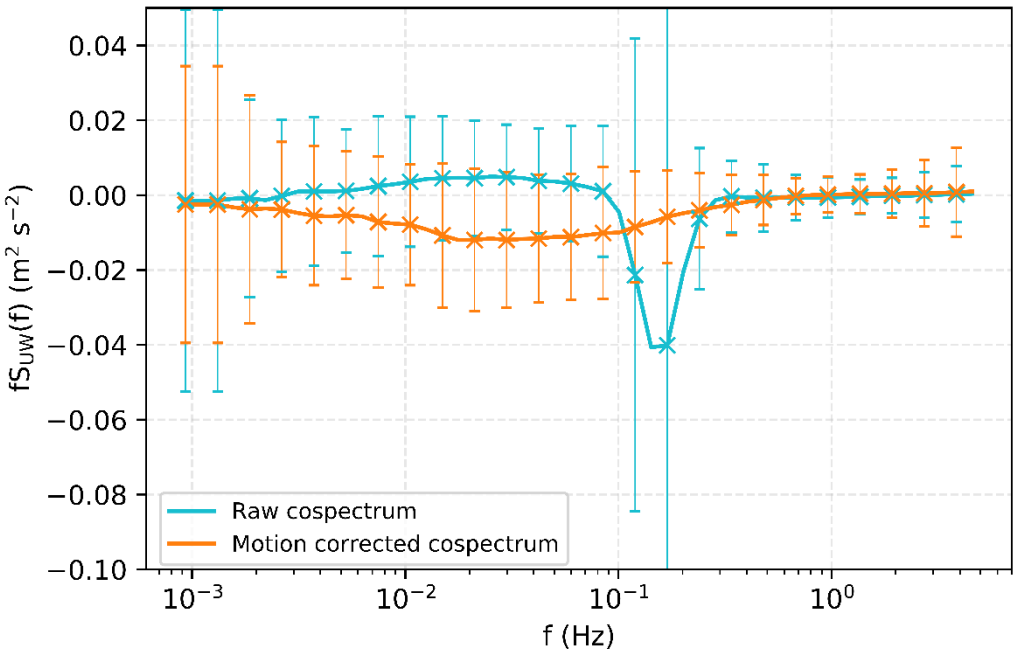

Figure S1. Mean momentum cospectrum $S_{UW}(f)$ before (cyan line) and after (orange line) motion correction for cruise JR18007. Error bars represent the standard deviation of $S_{UW}(f)$. For the raw cospectrum, there is a spectral peak in the frequency of 0.1-0.3 Hz which is the typical frequency of the ocean waves (swell) and ship motion.

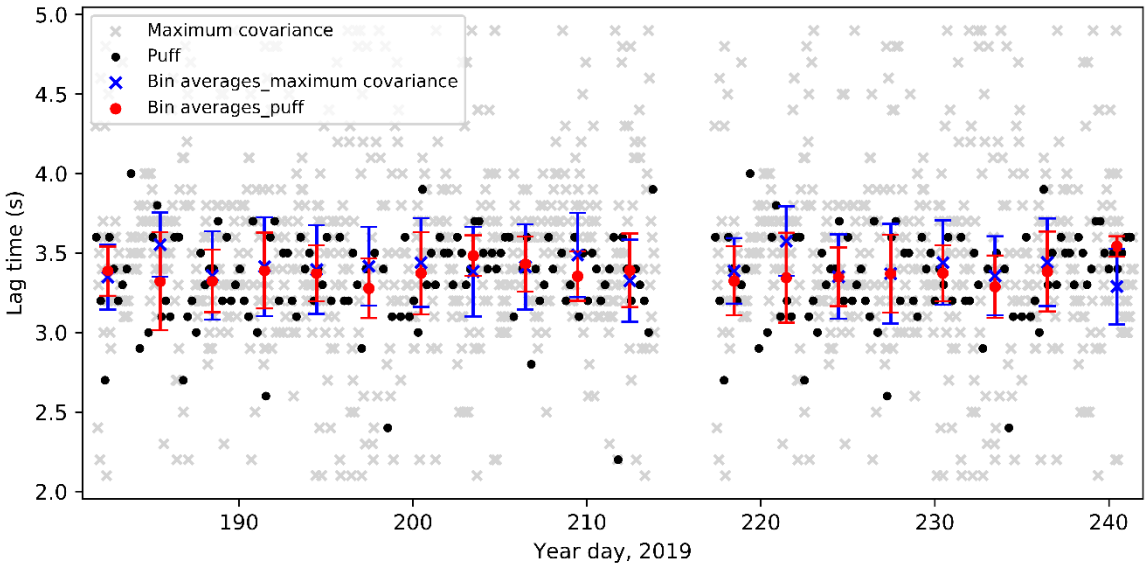

Figure S2. Time series of time lags for two Arctic cruises. Grey crosses represent the lag time estimated by maximum covariance method and the blue crosses represent 3 day (72 hours) bin averages with error

bars representing the standard deviation. Black filled circles represent the lag time estimated by nitrogen puff method and red circles represent 3 days bin averages with error bars represents the standard deviation. The gap in data between year day 213 and 217 is due to the break between cruise JR18006 and JR18007.

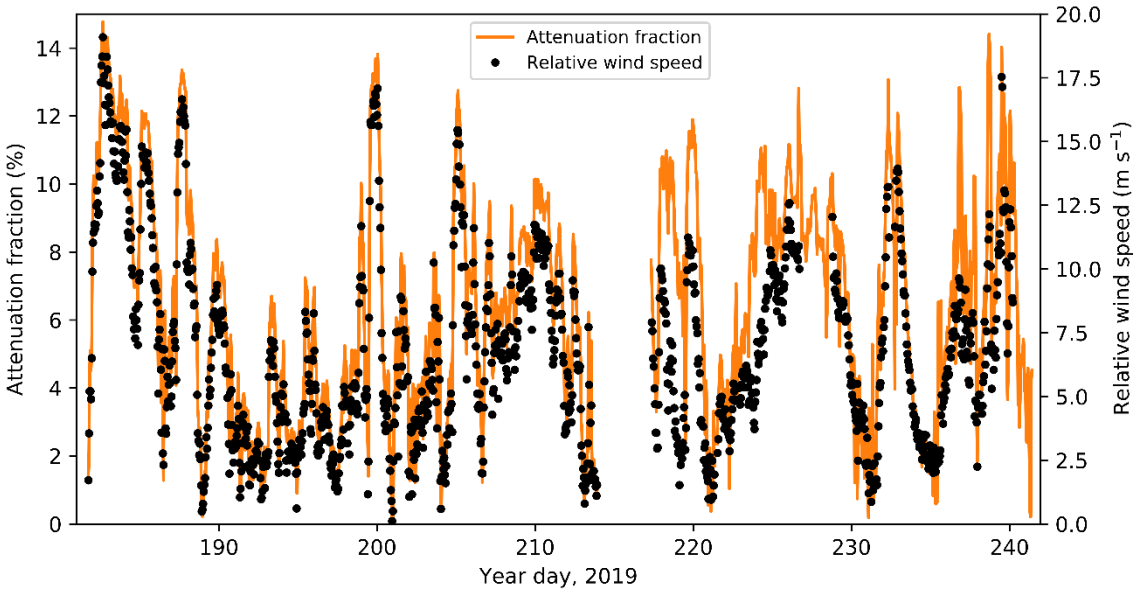

Figure S3. Time series of flux attenuation fraction and relative wind speed for two Arctic cruises. The gap in data between year day 213 and 217 is due to the break between cruise JR18006 and JR18007.

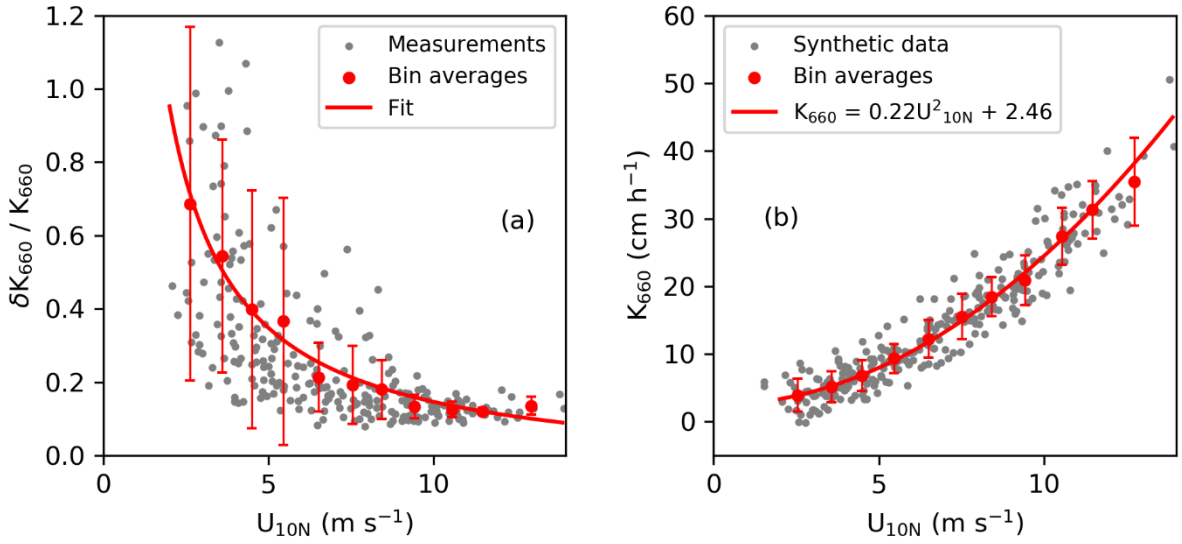

Figure S4. (a) Relative uncertainty in the gas transfer velocity (K_{660}) due to the uncertainty in the EC flux, and (b) the synthetic K_{660} data versus wind speed. Red circles in panel (a) represent the 1 m s^{-1} bin averages of the relative uncertainty data with error bars representing standard deviation. The red curve

in panel (a) represents a least square fit: $\frac{\delta K_{660}}{K_{660}} = 1.83 \times U_{10N}^{-1} - 0.036$ (R^2 = 0.36). Red circles in panel (b) represent the 1 m s^{-1} bin averages of the synthetic K_{660} with error bars representing standard deviation. The red curve in panel b represents the quadratic fit of the K_{660} from the cruise JR18007.

EC CO_2 flux data quality control

The overall aim of the quality control process is to remove data during periods when conditions were clearly unfavourable for EC measurements. These include excessive ship manoeuvres (invalidating motion correction of winds), winds from the stern sector (large flow distortion and contamination in CO_2 signal from ship exhaust), and large variability in winds and CO_2 (non-stationary). We do not attempt to filter spectrally for poorly resolved irregularities at low frequencies because the CO_2 cospectra tend to be very noisy. Given a large enough dataset, such low frequency variability should mostly average out. The specific filtering criteria are similar to Blomquist et al., 2014 and Blomquist et al., 2017, and are listed in Table S1.

Table S1. Filtering criteria (within 20 minutes averaging intervals) of EC fluxes for two Arctic cruises (the criteria for AMT cruises are similar to Arctic cruises). The right column points out the number of segments (percentage) of valid flux data which satisfy the filtering criteria by each stage of the quality control sequence.

	Criteria	Segments (percentage) passed	
		JR18006	JR18007
Wind	Standard deviation in ship heading < 40° Range in ship heading < 60° Change in ship heading between two adjacent segments < 60° Standard deviation in ship speed < 1 m s^{-1} Change in ship speed between two adjacent segments < 1.5 m s^{-1}	1923 (83.0)	1356 (78.6)
	| Relative wind direction | < 140°	1813 (78.3)	1318 (76.4)
	Standard deviation in Relative wind direction < 40°	1802 (77.8)	1300 (75.4)
	Tilt in wind speed < 10°	1741 (75.2)	1283 (74.4)
CO_2	Range in CO_2 mixing ratio < 2 ppm | Trend in CO_2 mixing ratio | < 2 ppm h^{-1}	1419 (61.3)	1224 (71.0)
CO_2 flux	Valid wind and CO_2	1741 (75.2)	1283 (74.4)

| Horizontal flux | < 0.08 ppm m s^{-1}	1375 (59.4)	1199 (69.5)

References

Blomquist, B. W., Huebert, B. J., Fairall, C. W., Bariteau, L., Edson, J. B., Hare, J. E. and McGillis, W. R.: Advances in Air-Sea CO_2 Flux Measurement by Eddy Correlation, Boundary-Layer Meteorol., 152(3), 245–276, doi:10.1007/s10546-014-9926-2, 2014.

Blomquist, B. W., Brumer, S. E., Fairall, C. W., Huebert, B. J., Zappa, C. J., Brooks, I. M., Yang, M., Bariteau, L., Prytherch, J., Hare, J. E., Czerski, H., Matei, A. and Pascal, R. W.: Wind Speed and Sea State Dependencies of Air-Sea Gas Transfer: Results From the High Wind Speed Gas Exchange Study (HiWinGS), J. Geophys. Res. Ocean., 122(10), 8034–8062, doi:10.1002/2017JC013181, 2017.