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LETTERS TO THE EDITOR

A reassessment of the gas transfer velocity – wind speed relationship from the Siblyback Lake data

By JOYCE KWAN and PETER A. TAYLOR*, *Department of Earth and Atmospheric Science, York University, 4700 Keele Street, North York, Ontario, Canada M3J 1P3*

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ABSTRACT

Gas transfer velocity results presented by Upstill-Goddard et al. for lakes are reviewed. An alternative analysis and interpretation of their wind data lead to gas transfer velocities in good agreement with other studies.

The paper by Upstill-Goddard et al. (1990) reporting on work on Siblyback Lake and Dozmary Pool in SW England suggests that, for 10-m wind speeds greater than about 5 ms^{-1}, the gas transfer velocity for lakes may be less than the open sea values summarized by Liss and Merlivat (1986). In the Siblyback Lake study, 10-m winds were obtained by extrapolation from measurements at 1.5 m and 3 m, kindly provided to us by the original authors, assuming a logarithmic profile,

$$U(z) = (u_*/\kappa) \ln(z/z_0). \quad (1)$$

This procedure is completely appropriate, but a closer inspection of the profiles reveals that the z_0 values implicit in the extrapolations, (listed in the left-hand columns of Table 1), are generally much too high for a water surface since they range from 0.06 to 0.5 m rather than the expected range of $z_0 \approx 0.000001$ to 0.001 m (cf. Oke, 1987, Arya, 1988). The anemometer installation, siting and calibration procedures (Watson, personal communication) appear to have been quite satisfactory and the reason for the anomalously high z_0 values is not completely clear. However, examination of raw (4 min) wind data strongly suggests that the recorded 1.5 m level winds were often too low, possibly due to data logger resolution problems. In view of this, we have made alternative estimates of u_* and extrapolations to 10 m using only the 3 m wind measurement and assuming a value of 0.0001 m for the roughness length of the water surface. We consider this to be a representative value for a water surface at wind speeds of order 5 ms^{-1}. Values of U_{10}, U_1 and u_* values obtained in this way are listed in the right-hand columns of Table 1. U_1 values are included since a lower-level wind measurement may be preferred over lakes where limited over-water fetch may be a factor. A significant reduction in the U_{10} estimates obtained in this way compared to the original values presented by Upstill-Goddard et al. is apparent. If we use the revised U_{10} values, the $k(U_{10})$ relationship is modified considerably as shown in Fig. 1. For $U_{10} > 5$ ms^{-1}, the revised data are much closer to earlier results (represented by the Liss - Merlivat curve), although k values are now high relative to the Liss-Merlivat formula for $U_{10} < 5$ ms^{-1}.

A comparison is made in Fig. 2 with data from a recent gas exchange study using SF_6 on Lake 302N (Crusius and Wanninkhof, personal communication) which focused on lower wind speeds ($U_1 < 5$ ms^{-1}). With the revised U_1 wind estimates, the Siblyback Lake data are in good agreement with Crusius and Wanninkhof's observations for $U_1 < 4$ ms^{-1}, but suggest that the

* Corresponding author.

Table 1. *A Comparison of estimated wind speeds over Siblyback Lake*

	Upstill-Goddard's original results and corresponding z_0 and u_* values			Extrapolation from the measured 3 m wind speeds assuming a logarithmic profile with $z_0 = 0.0001$ m		
Date 1988	U_{10} (ms^{-1})	z_0 (m)	u_* (ms^{-1})	U_{10} (ms^{-1})	U_1 (ms^{-1})	u_* (ms^{-1})
24 March	10.30	0.09	0.87	8.60	6.88	0.30
8 April	5.10	0.20	0.52	3.91	3.13	0.14
11 April	3.90	0.51	0.52	2.57	2.05	0.09
12 April	4.80	0.35	0.58	3.46	2.77	0.12
13 April	5.70	0.27	0.63	4.24	3.40	0.15
15 April	10.30	0.52	1.38	6.81	5.45	0.24
18 April	6.10	0.14	0.58	4.91	3.93	0.17
19 April	6.00	0.32	0.69	4.36	3.48	0.15
20 April	4.20	0.07	0.35	3.57	2.86	0.12
21 April	4.60	0.10	0.40	3.80	3.04	0.13
22 April	5.90	0.44	0.75	4.02	3.22	0.14
23 April	9.50	0.16	0.92	7.48	5.99	0.26
25 April	4.10	0.08	0.35	3.46	2.77	0.12
1 May	12.20	0.34	1.44	8.82	7.06	0.31
3 May	12.90	0.07	1.04	10.94	8.76	0.38
4 May	5.20	NA	NA	5.81	4.65	0.20
9 May	8.30	0.16	0.81	6.59	5.27	0.23
10 October	6.70	0.36	0.81	4.76	3.81	0.17
14 October	6.10	0.48	0.81	4.13	3.31	0.14
17 October	6.20	0.47	0.81	4.19	3.35	0.15
19 October	8.40	0.22	0.88	6.43	5.15	0.22
21 October	6.00	0.34	0.72	4.32	3.46	0.15
24 October	8.60	0.27	0.95	6.40	5.12	0.22
26 October	9.60[1]	0.17	0.95	7.58	6.07	0.26
23 November	3.80	0.61	0.55	2.43	1.95	0.08
25 November	5.20	0.53	0.70	3.41	2.72	0.12
28 November	5.80	0.29	0.65	4.25	3.40	0.15
30 November	5.30	0.20	0.54	4.05	3.24	0.14
2 December	4.20	0.44	0.53	2.85	2.28	0.10
5 December	7.90	0.09	0.66	6.59	5.27	0.23
7 December	8.80	0.04	0.65	7.69	6.16	0.27
9 December	5.70[2]	0.08	0.47	4.78	3.82	0.17
12 December	6.70	0.06	0.51	5.73	4.58	0.20
14 December	7.10	0.17	0.70	5.55	4.44	0.19

Notes: NA: Calculations of z_0 and u_* are not available because both 1.5-m and 3-m wind speed measurements are 5.2 ms^{-1}.

[1,2] These values are based on our calculations. Upstill-Goddard et al. (1990) give 9.1 and 6.4 ms^{-1} in their values.

Crusius and Wanninkhof formula (for instantaneous $k(U_1)$ relationships) would overestimate the Siblyback Lake gas transfer velocities for $U_1 > 4$ ms^{-1}, irrespective of differences between steady and varying winds.

In summary, we would argue that the extrapolated 10 m winds reported by Upstill-Goddard et al. (1990) for the Siblyback Lake experimental study are suspect. An alternative estimate of 10 m and 1 m winds leads to gas transfer velocity – wind speed results which are compatible with the Liss-Merlivat (1988) open ocean formula for $U_{10} > 6$ ms^{-1}. In the lower wind regime, $U_1 < 4$ ms^{-1}, the Siblyback Lake $k(U_1)$ results are compatible with the data presented by Crusius and Wanninkhof, personal communication.

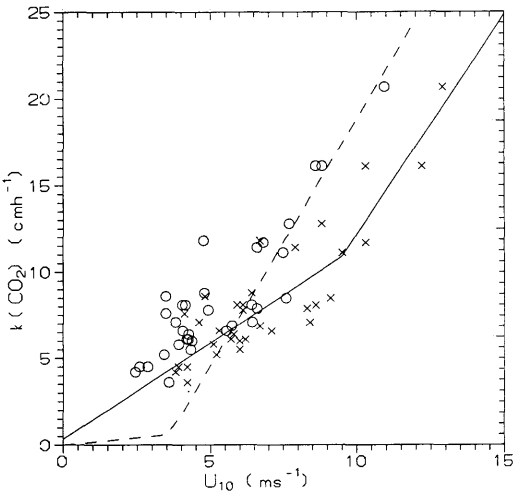

Fig. 1. Gas transfer velocity (CO_2, Sc = 600) versus wind speed results from the Upstill-Goddard et al. (1990) Siblyback Lake study

————	Upstill-Goddard least-squares fit.
------	Liss-Merlivat (1986) model equations.
X	Upstill-Goddard (1990) results, their original U_{10}.
○	Upstill-Goddard (1990) results, our U_{10} estimates.

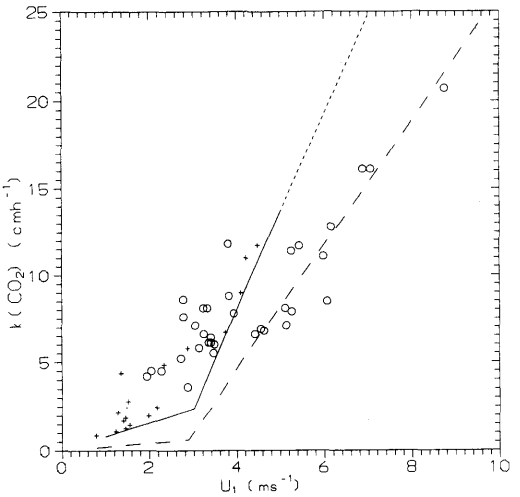

Fig. 2. Gas transfer velocity (CO_2, Sc = 600) versus 1 m wind speed from the Upstill-Goddard et al. (1990) Siblyback Lake study compared to measurements by Crusius and Wanninkhof.

————	Crusius and Wanninkhof formula, $0 < U_1 < 5$ ms^{-1}.
----------	Crusius and Wanninkhof formula-extrapolated.
------	Liss-Merlivat (1986) model equations, adjusted to 1 m.
+	Crusius and Wanninkhof data, ELA Lake N302.
○	Upstill-Goddard (1990) results, new U_1 estimates.

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