Uncertainty in Covariance Transfer Velocity Estimates: Effect of ΔpCO_2
By C. Fairall and W. McGillis, April 2006

If we assume the error in transfer velocity is due to error in the covariance flux measurement only, then the uncertainty in the transfer velocity, k, is:

$$\delta k / k = \frac{\delta(\overline{w'x'})}{\alpha k \Delta X} \tag{1}$$

where α is the solubility and ΔX the ΔpCO_2. The covariance flux in GASEX-98 was computed as:

$$\overline{w'x'} = \overline{w'x'}_{meas} - \overline{w'x'}_{bias} \tag{2}$$

where an estimate of the covariance bias was subtracted from the measured values (McGillis et al., JGR, vol 106, 2001). The bias is principally due to crosstalk between CO_2 with water vapor and ship motion (Fairall et al., BLM, vol 96, 2000).

We can then estimate the error in k as:

$$\delta k / k = \frac{\delta(\overline{w'x'})_{sample}}{\overline{w'x'}} + \frac{\delta(\overline{w'x'})_{bias}}{\alpha k \Delta X} \tag{3}$$

which is the sum of sampling uncertainty and the uncertainty in determining the bias. The sampling uncertainty is given by Fairall et al. (2000):

$$(\delta k / k)_{sample} = \frac{3\sigma_w / u_*}{\sqrt{T/\tau}} \left[1 + \left(\frac{\sigma_{xb} u_*}{2\alpha \Delta X k} \right)^2 + \frac{\Phi_{xn}}{\tau} \left(\frac{u_*}{2\alpha \Delta X k} \right)^2 \right]^{1/2} \tag{4}$$

Where σ_w is the standard deviation of vertical velocity, u_* the friction velocity, T the averaging period (e.g., 30-min), τ=12z/u the integral time scale, σ_{xb} the standard deviation of CO_2 concentration not associated with the surface flux, Φ_{xn} the broadband noise level of the CO_2 sensor, z the sensor height, and u the wind speed.

It turns out that the sampling uncertainty for k was measured in GASEX-98 (Fig. 1). These results can be fitted by (4) using σ_{xn}=0.03 μA and Φ_{xn}=0.027 μA^2 sec. For GASEX-98 the uncertainty in the bias was about 0.6 mol/m^2/yr. Using (4) we can estimate the sampling error as a function of ΔpCO_2 (Fig. 2). Even if the bias uncertainty is as large as 1.0 mol/m^2/yr, it will still make a negligible contribution to the error for wind speeds in the 5-20 m/s range.

So what does this mean? If SO GasEx is as successful as GASEX-98, then we will get flux data spread over a reasonable range of wind speeds (5- 20 m/s) with about 40 values per wind speed interval. Since the square root of 40 is about 6, we can divide the values in Fig. 2 by 6 to get an estimate of how well we constrain the estimates of mean transfer velocity. At a wind speed of 10 m/s we would constrain the values to about 50% at $\Delta pCO_2 = 20$ and 13% at ΔpCO_2 of 100. At u=20 m/s things are about a factor of two more favorable.

Regarding the possible use of the gradient method. Using an approximation for k-theory using the flux-profile technique:

$F = k\alpha \Delta pCO_2 = Bzu_* dX/dz$

$dX/dz = k/(zu_*)\ \Delta pCO_2$ *constants

If k is a stronger function of wind than u*, dX/dz goes up with wind at fixed ΔpCO_2.

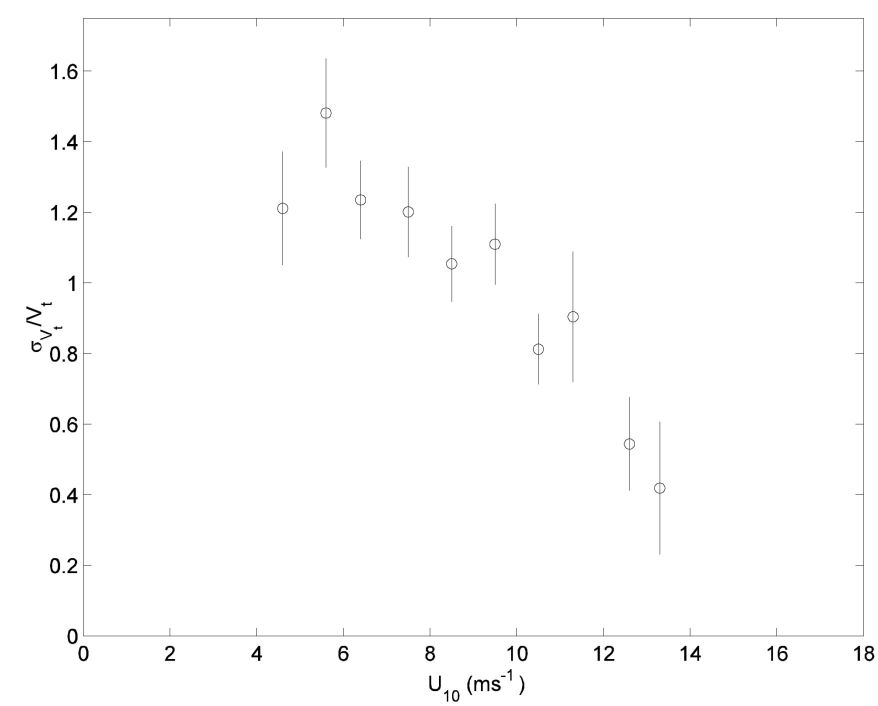

Figure 1. Uncertainty in CO_2 transfer velocity as a function of wind speed from GASEX-98.

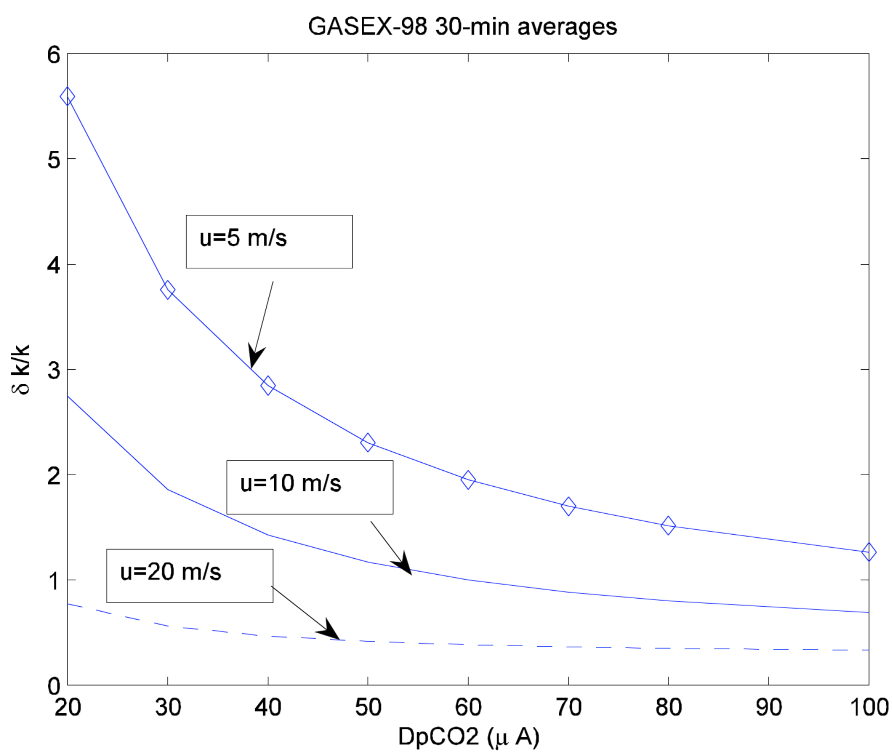

Figure 2. Estimate of sampling uncertainty of transfer velocity for a 30-min average as a function of ΔpCO_2 at a wind speed of 5, 10 and 20 m/s.