Air-sea CO_2 exchange coefficients deduced from satellite QSCAT wind speeds from 1999 to 2006

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Introduction

The absolute calibration of the relationship between air-sea CO_2 tranfer velocity, k, and wind speed, U, is in debate for a long time because global average of CO_2 exchange coefficient, K, deduced from GEOSECS oceanic ^{14}C inventory and from experimental k-U relationships disagreed. Recently, estimates of oceanic ^{14}C inventories have been revisited towards lower values, leading to lower global k average [*Naegler et al.*, 2006]. In addition, a new k-U relationship has been proposed based on new k measurements performed at sea in high wind speed conditions [*Ho et al.*, 2006].

In this poster, we use recent satellite QSCAT wind speeds to derive global fields of K using past and new k-U relationships. We also discuss the accuracy of QSCAT K based on new comparisons between buoy and QSCAT wind speeds.

CO_2 exchange coefficients derived from satellite wind speeds

Methodology:

We compute k for each 25km QSCAT satellite wind speed using 4 k-U relationships (see Figure 1):

-The Liss and Merlivat (1986) relationship deduced from process studies in wind tunnel and calibrated with lake measurements.(k_{LM})

-The Wanninkhof (1992) relationship deduced by assuming (1) k is proportionnal to U^2, (2) the global distribution of U is a Rayleigh distribution and (3) the global k average is constrained by the Broecker et al. (1985) ocean ^{14}C inventory .(k_W)

-The Nightingale et al. (2000) relationship deduced from in situ tracer measurements (SF_6, ^3He) performed at sea and assuming a second order polynomial k-U relationship. (k_N)

-The Ho et al. (2006) relationship deduced from measurements performed during the SAGE experiment in the Southern Ocean assuming a quadratic k-U dependency. (k_H)

CO_2 exchange coefficients, K, are deduced from k and Schmidt number, Sc, and CO_2 solubility deduced from weekly 1° Reynolds SST. Using rea l fields of wind speed and SST, we find a ratio between mean K and mean k at Sc=660: $<K[mol/m2/yr/\mu atm]>global/<k_{660}$ [cm/hr]>global = 3.02 10^{-3}.

weekly and monthly 1°x1° maps of Kare deduced using CERSAT krigeage interpolation method. (see example on Figure 2)

K maps are available in close real-time on ftp.ifremer.fr , *directory: /ifremer/cersat/products/gridded/kco2-quikscat/*

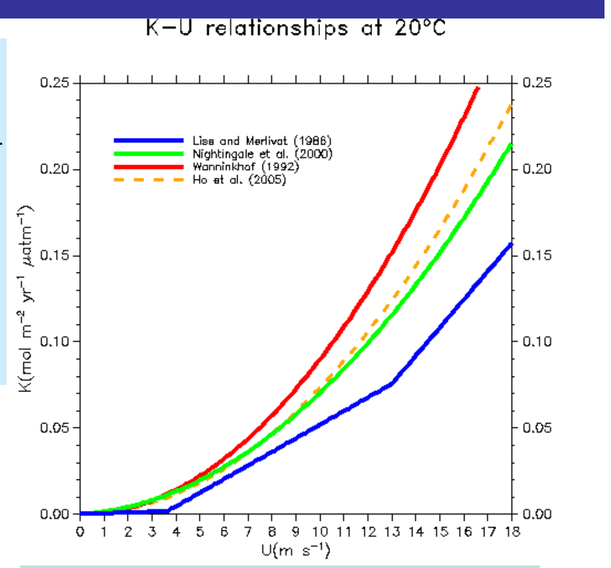


Fig1: K-U relationships at 20°C (Sc=600)

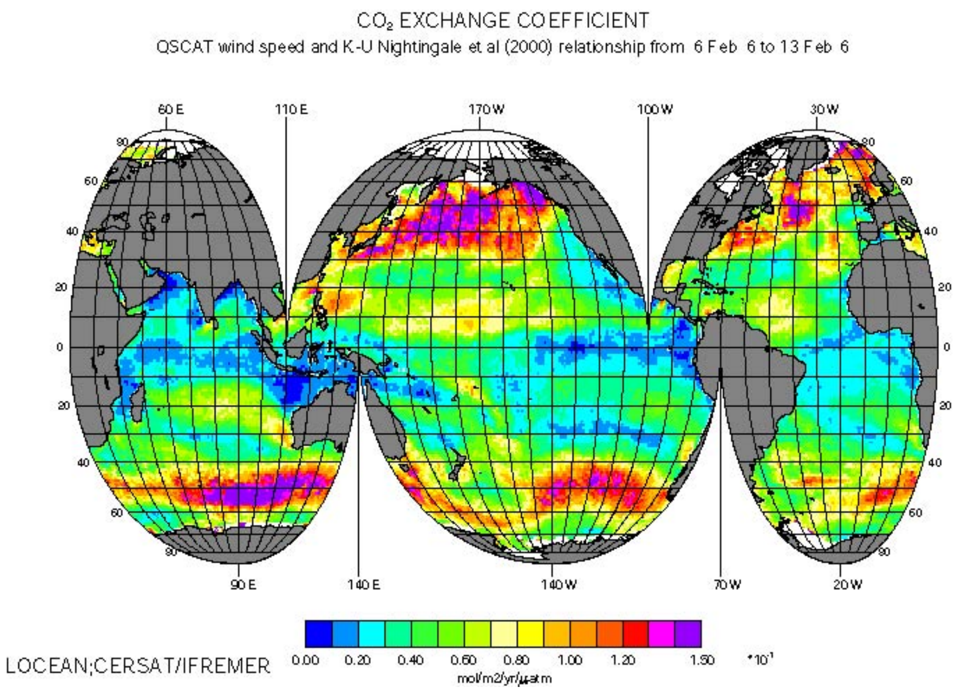


Figure 2: Global map of K deduced from QSCAT wind speed , Reynolds SST and Nightingale et al(2000) relationship.(scale from 0 to 0.015 mol/m²/yr/µatm)

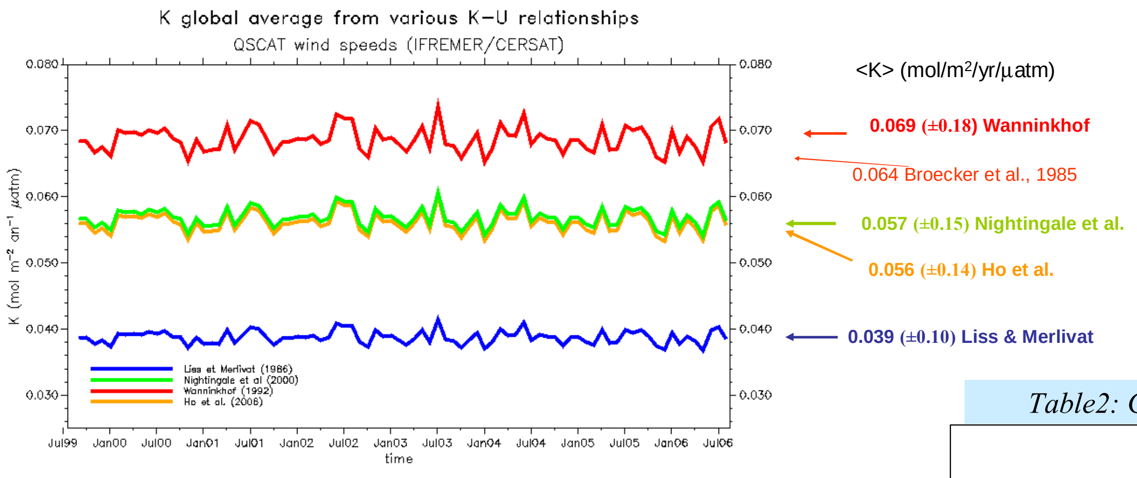


Figure 3: Global average of K deduced from QSCAT wind speed

Table1: Global average of k_{660} deduced from QSCAT wind speed

	$<k_W>$	$<k_H>$	$<k_N>$	$<k_{LM}>$
$<k_{660}>$ global (cm hr^{-1})	22.2	18.6	18.8	12.8

Table2: Global average of k_{660} deduced from ^{14}C inventories

	GEOSECS inventories by [Broecker et al., 1985] , used by [Wanninkhof, 1992]	New ^{14}C estimate (Naegler et al., 2006)
$<k_{660}>$ global (cm hr^{-1})	21.9 +/- 3.3	16.7 +/-2.9

K QSCAT global averages shown on Fig. 3 correspond to global mean values of k_{660} reported in Table 1. In Table 2, we report <k660> deduced from 14C inventories.

<kH> and <kN> are very similar and 2cm hr^{-1} higher than Naegler estimate: this is within the error bar of this estimate.

Accuracy of QSCAT wind speeds

Earlier comparisons of QSCAT with in situ wind speeds [*Bourassa et al.,* 2003; *Ebuchi et al.,* 2002; *Freilich and Vanhoff,* 1999] indicate a precision of QSCAT U between 1 and 1.2m s^{-1} in conditions without rain. These studies were mostly based on measurements taken in the equatorial region and in the northern hemisphere. Comparison with numerical weather prediction (NWP) models [*Chelton and Freilich,* 2005] shows no systematic bias between QSCAT and NCEP U but QSCAT U were higher than ECMWF U by 0.4m s^{-1} on average.

We provide a new set of comparison between QSCAT and in situ buoy wind speeds in the Northern Atlantic during the POMME experiment and in the Southern Ocean, in high wind speed conditions, far from coasts and in regions very rarely sampled, especially in winter.

Methodology:

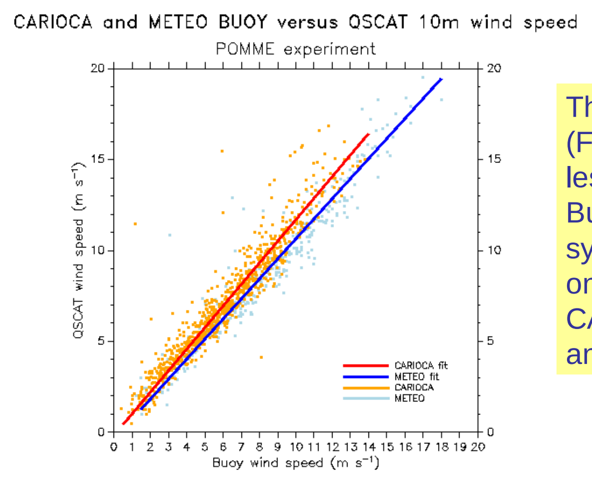
During POMME experiment, a moored meteorological buoy records U at 4.5m height and 3 CARIOCA drifters record U at 2m height (09/02/01 to 31/12/01;CARIOCA equipped with cup anemometers (Debucourt type))

In the Southern Ocean, 5 CARIOCA drifters record U at 2m height with either cup anemometer, either sonic anemometer.

Neutral wind speed at 10m height (corrected for atmospheric stability; equivalent to QSCAT measurements), U10n, was deduced from these measurements using the Liu and Tang (1996) algorithm.

Each in-situ wind speed is colocated with QSCAT wind speed in a radius of 12.5km and 30mn. Fits between in situ and QSCAT U are calculated as orthogonal regressions. The fit quality is quantified by the rms of QSCAT U minus the fit estimate (rms of (Y-Yfit)).

Northern Atlantic (POMME experiment)



The scattering of this comparisons (Figure 4) is remarkably low (rms less than 0.9m s-1);

Buoy 10m wind speeds systematically lower than QSCAT ones on average by 16% for CARIOCA-Debucourt anemometer and 6% for the moored buoy.

Figure 4: QSCAT U10n versus U10n from CARIOCA (Debucourt anemometer) (orange points) and meteorological buoy (light blue points) during POMME experiment (Northern Atlantic).

Southern Ocean

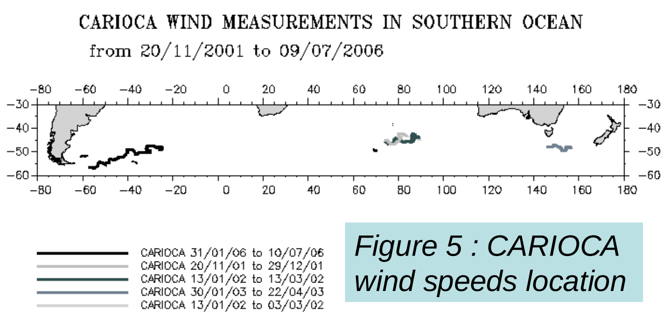


Figure 5 : CARIOCA wind speeds location

The scattering of these comparisons (Fig 6) is as low as in the northern Atlantic, about 1m s^{-1}. The fit between the CARIOCA-Debucourt anemometer and QSCAT wind speeds is very similar to the one found over the POMME area.

For the same QSCAT wind speed value, sonic anemometer wind speeds are about 1m s^{-1} higher than Debucourt anemometer wind speeds.

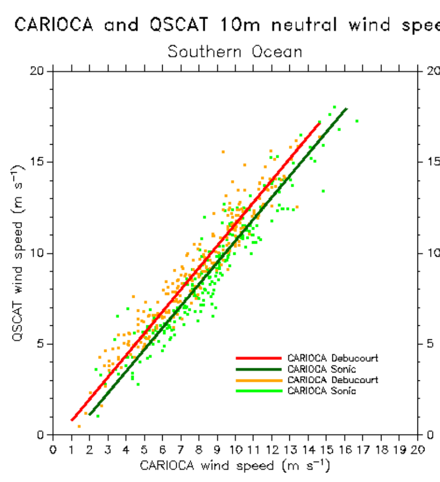


Figure 6 : QSCAT versus CARIOCA wind speed. CARIOCA wind speeds measured with Debucourt anemometer (red) and with Sonic anemometer (green) in Southern Ocean.

Accuracy of QSCAT wind speeds is very similar in the northern Atlantic and in the Southern Ocean.

Buoy U10n are systematically lower than QSCAT; given that fits obtained with CARIOCA-Debucourt anemometers are lower than with other anemometers, we cannot exclude a 8% underestimate of CARIOCA-Debucourt U10n. Nevertheless, it remains a 5% difference between QSCAT and buoy U10n. This difference is observed in several oceans and at various seasons, so it is unlikely that it is due to anemometer flaw. On another hand, in order to increase the conversion factor between U2m and U10m by 5%, the drag coefficient Cd should reach 2.5 10^{-3} at 15m/s, which is much larger than Cd measured during POMME experiment (1.7 10^{-3} at 15m s^{-1}) .

Hence, the true wind speed is probably between QSCAT U and QSCAT U minus 5%. With QSCAT U minus 5%, $<kN_{660}>$ becomes equal to 17.3cm hr^{-1}.

Summary

Global k_{660} values obtained with the [*Nightingale et al.*, 2000] and the [*Ho et al.*, 2006] k-U relationships are very close and within the error bars of the independent k_{660} average deduced from new oceanic ^{14}C inventory by [*Naegler et al.*, 2006]. Nevertheless they remain 12% higher than this reference mean ^{14}C value.

New QSCAT-buoy wind speed comparisons in high wind speed conditions confirm the excellent precision of QSCAT wind speeds (rms difference of 1m s^{-1}). However, they leave a possible overestimate of QSCAT wind speeds by 5%.

If QSCAT U10n are lowered by 5%, the mean global k_{660} derived using the [*Nightingale et al.*, 2000] relationship differs from [*Naegler et al.,* 2006] mean ^{14}C value by only 3%.

The mean global k_{660} value derived using the [*Ho et al.*, 2006] is not modified as this relationship was calibrated using QSCAT wind speed.

This study points out the importance of acquiring very precise wind speed and sea state measurements during sea experiments for better quantification of k-U relationships.

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