# Discussion/comments regarding "Distribution and sea-air fluxes of biogenic gases and relationships with phytoplankton and nutrients in the central basin of the South China Sea during summer" by X. Zhai, H.-H. Zhang, G.-P. Yang, J.-L. Li, D. Yuan

Dag Myrhaug

Department of Marine Technology

Norwegian University and Science and Technology (NTNU)

NO-7491 Trondheim, Norway

E-mail address: dag.myrhaug@ntnu.no

## Abstract

The purpose of this discussion is to demonstrate how a formula used by Zhai et al. (2018) can be utilized to estimate the air-sea fluxes of biogenic gases based on wind statistics. Results are exemplified using long-term mean wind speed statistics from the northern North Sea.

**Keywords:** Sea-air flux; Sea-air exchange; Mean wind speed statistics; Climate change

# 1. Discussion

The paper by Zhai et al. (2018) (hereafter referred to as Z18) presented a comprehensive review of the literature on the distribution and sea-air fluxes of biogenic gases and relationships with phytoplankton and nutrients in the ocean. The review also included formulae used for saturation and sea-air flux calculations. In section 2.5 of Z18, the authors presented the following simplified equation for calculating the instantaneous sea – to – air fluxes $F$ *(mass area$^{-1}$ time$^{-1}$)*

$$F = C_w\left(\frac{Sc}{660}\right)^{-0.5} f \tag{1}$$

Where $f$ $(length\ time^{-1})$

$$f = A_1U + A_2U^2\,;\ (A_1, A_2) = (0.33,\ 0.222) \tag{2}$$

Here $U$ *(length time$^{-1}$)* is the *in situ* mean wind speed at 10 m elevation above the sea surface,

$C_w$ $(mass\ volume^{-1})$ is the concentration of the trace gases in the surface seawater, and $Sc$ (dimensionless) is the Schmidt number, i.e. the kinematic viscosity of water divided by the diffusion coefficient of trace gases in water. It should be noted that alternative formulations of $F$ exist in the literature (see the references in Z18 as well as in Wanninkhof (2014)). For given values of $C_w$ and $Sc$, $F$ will only depend on $U$. Thus, $F$ can be obtained from known statistics of $U$ for a study ocean area.

Wind statistics are often available as parametric models of the cumulative distribution function (*cdf*) (or the probability density function (*pdf*)) of $U$ ; a review is provided by Bitner-Gregersen (2015). The results in the present note are exemplified by adopting the Johannessen et al. (2001) *cdf* of $U$, which is based on hourly values of $U$ from wind measurements in the northern

North Sea covering a 25 year period from 1973-1999. This *cdf* of $U$ is given by the following two-parameter Weibull model

$$P(U) = 1 - \exp\left[ -(\frac{U}{\theta})^{\beta} \right]; U \geq 0 \tag{3}$$

with the Weibull parameters $\theta = 8.426\,\mathrm{m\,s^{-1}}$ and $\beta = 1.708$.

Long-term statistical properties of $F$ can now be obtained based on Eqs. (1) to (3). Here the basic statistical quantities are considered, i.e. the expected (mean) value of $F$, $E[F]$, and the variance of $F$, $Var[F]$, which are proportional to $E[f]$ and $Var[f]$, respectively, given by (Bury, 1975)

$$E[f] = A_1 E[U] + A_2 E[U^2] \tag{4}$$

$$\begin{aligned} Var[f] &= E[f^2] - (E[f])^2 \\ &= A_1^2 E[U^2] + 2A_1 A_2 E[U^3] + A_2^2 E[U^4] \\ &\quad - A_1^2 (E[U])^2 - 2A_1 A_2 E[U] E[U^2] - A_2^2 (E[U^2])^2 \end{aligned} \tag{5}$$

Thus, $E[U^n]$ for a Weibull distributed variable is required, and is given by Bury (1975),

$$E[U^n] = \theta^n \Gamma(1 + \frac{n}{\beta}) \tag{6}$$

where $\Gamma$ is the gamma function.

Then, according to Eqs. (2) to (6), the results are

$$E[f] = 19.58\,\mathrm{m\,s^{-1}} \tag{7}$$

$$Var[f] = 463.10\,\mathrm{m^2\,s^{-2}} \tag{8}$$

Thus, for this example, the standard deviation of $F (= (Var[F])^{0.5})$ is 110% of $E[F]$, which reflects the large scatter in these wind speed data.

If $E[U]$ is known, an alternative to the stochastic method used here, would be to use the approximate method of estimating $F$ by replacing $U$ with $E[U]$ in Eqs. (1) and (2). For this example $E[U] = 7.52$ ms$^{-1}$, which substituted in Eq. (2) gives $f = 15.04$ ms$^{-1}$. Thus, the approximate to stochastic method ratio of $F$ is 15.04/19.58 = 0.77. Overall, the stochastic method should be used as the stochastic method features are taken into account consistently when compared to what the approximate method does.

A similar method as described in this note was presented in Myrhaug (2016, 2018). Myrhaug (2016) commented on the work of Iida et al. (2015) (who used a bulk formula similar to Eq. (1) for estimating the sea-air $CO_2$ flux, but as a function of $U^2$) using *cdfs* of $U$ based on two data sets, where one was the same as used here for the northern North Sea. Myrhaug (2018) extended the 2016 work by including *cdfs* of $U$ based on ten additional data sets. For these twelve data sets the standard deviation to mean value ratios of the sea-air $CO_2$ flux were in the range 0.32 to 1.18, and the approximate to stochastic method ratios were in the range 0.73 to 0.97.

Overall, the present method should be useful for estimating and assessing the air-sea fluxes of biogenic gases based on mean wind speed statistics for an ocean area.

## References


Bitner-Gregersen, E. M., 2015. Joint met-ocean description for design and operations of marine structures. *Appl. Ocean Res.* 51, 279-292.

Bury, K.V., 1975. *Statistical Models in Applied Science.* Wiley, New York.

Iida, Y., Kojima, A., Takatani, Y., Nakano, T., Sugimoto, H., Midorikawa, T., Ishii, M., 2015. Trends in $pCO_2$ and air-sea $CO_2$ flux over the global open oceans for the last two decades. *J. Oceanogr.* 71, 637-661.

Johannessen, K., Meling, T.S., Haver, S., 2001. Joint distribution for wind and waves in the Northern North Sea. In: *Proc. 11th Int. Offshore and Polar Engineering Conf.,* Stavanger, Norway, 17-22 June 2001, Vol. III, pp. 19-28.

Myrhaug, D., 2016. Discussion/comments regarding "Trends in $pCO_2$ and sea-air $CO_2$ flux over the global open oceans for the last two decades" by Y. Iida, A. Kojima, Y. Takatani, T. Nakano, H. Sugimoto, T. Midorikawa, M. Ishii, *J. Oceanogr.* 72, 661-662.

Myrhaug, D., 2018. Some aspects of sea-air $CO_2$ flux estimation from long-term mean wind speed statistics. *J. of Marine Env. Eng.* 10(2), 147-151.

Wanninkhof, R., 2014. Relationship between wind speed and gas exchange over the ocean revisited. *Limnology and Oceanography*: *Methods*. 12, 351-362.

Zhai, X., Zhang, H.-H., Yang, G.-P., Li, J.-L., Yuan, D., 2018. Distribution and sea-air fluxes of biogenic gases and relationships with phytoplankton and nutrients in the central basin of the South China Sea during summer. *Marine Chemistry* 200, 33-44.