

# solas event report

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## Eddy Covariance (EC) Air/sea Gas Flux Best Practice Workshop

28-30 March 2023  
London, UK



In March 2023, a 2.5-day international workshop was convened to discuss the major advances that have been made in the field of eddy covariance flux measurements. The aim was to consolidate current understanding to help prevent others from repeating past mistakes. The community assembled (~25 scientific experts from around the world) to discuss and begin the process of documenting the steps required to achieve best quality air/sea eddy covariance (EC) gas flux measurements from a moving platform. The focus was on air-sea carbon dioxide (CO<sub>2</sub>) fluxes, although many of the conclusions will be relevant to other marine gases. Workshop objectives were to:

1. Agree best practice for EC CO<sub>2</sub> flux system setup
2. Assess results from a data analysis intercomparison exercise
3. Agree best practice for EC data analysis and uncertainty estimation
4. Plan for a possible EC CO<sub>2</sub> flux intercomparison field experiment

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### Scheduled presentations included:

- Brian Butterworth: A need to dry?
- Jim Edson: Thoughts on the motion correction
- Yuanxu Dong: EC flux uncertainties - assessments and recommendations
- Marc Emond: Development of a new EC CO<sub>2</sub> sensor



**Figure 1:** Group picture of Eddy Covariance (EC) Air/sea Gas Flux Best Practice Workshop.

The workshop agenda focused primarily on facilitating discussion. The workshop was divided into 4 major discussion sessions:

- An optimal EC flux system setup
- An EC data processing intercomparison exercise
- Best Practice for EC air-sea flux measurements
- What would a future EC CO<sub>2</sub> flux intercomparison experiment look like?

We used the time very flexibly and hoped for lots of constructive contributions from the floor. We were very pleased with the engagement, input and enthusiasm showed by everyone!

During the meeting, the optimal setup for both ship- and tower-based measurements were outlined. A long time was spent on comparing different groups' processed fluxes using the same raw gas/wind/motion input data (this was sent to meeting participants ahead of time), and then relating the discrepancies in the processed fluxes

to the differences in the flux processing steps. The main findings from this exercise are summarised below:

- Discrepancies in different groups' fluxes are small in tower-based measurements, and these were smaller than the discrepancies for ship-based measurements.
- Discrepancies in fluxes are relatively greater for CO<sub>2</sub> than for momentum ( $u^*$ ) and sonic heat flux.
- The way that the motion contamination in the CO<sub>2</sub> signal is corrected appears to be the largest source of discrepancy.

As a group, we agreed upon the optimal workflow for EC data processing. We also identified areas where significant improvements in air/sea CO<sub>2</sub> flux measurements can be made, including reducing the motion-sensitivity in the CO<sub>2</sub> sensor. Finally, we discussed potential future intercomparison experiments to examine issues such as the motion-sensitivity in CO<sub>2</sub> as well as the effect of drying the sample air stream for CO<sub>2</sub>

flux measurements. A paper is now in preparation, summarising the main outcomes from the meeting.

We are extremely grateful to Imperial College London for hosting the workshop, and for the financial support provided by SOLAS toward participants travel and accommodation costs.

### Workshop Organisers

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**Yuanxu Dong** studied Marine Science for a Bachelor's and Physical Oceanography for a Master's at the Ocean University of China. In 2019, Yuanxu moved to the UK to conduct his PhD study and got the degree in 2023. Now, Yuanxu starts his postdoc with the Humboldt Fellowship at GEOMAR and Heidelberg University to investigate the role of bubbles in the air-sea gas exchange.

Dong, Y.X.<sup>1,2</sup>

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The EC technique has emerged as a powerful tool for direct measuring air-sea CO<sub>2</sub> fluxes and studying the underlying mechanisms of gas exchange over the past two decades. During my inaugural year as a PhD student, I analysed the inherent uncertainties in EC air-sea CO<sub>2</sub> flux measurements (Dong *et al.*, 2021), which significantly advanced our understanding of the EC technique. By doing this work, I realised that an optimal system setup and appropriate data processing are critical to minimise the uncertainties associated with EC flux measurements. The large terrestrial EC community has established agreements regarding the standardisation of instrument setup and data processing. However, such agreements are yet to be achieved in the small ocean EC community, which leads to reduced comparability among measurements from different campaigns. The EC workshop offered a valuable platform to address

such challenges and achieve consensus among the ocean EC community members. The outcome of such efforts will enhance our confidence in using EC to understand air-sea gas transfer processes. Personally, the presentation of my research on uncertainties in EC CO<sub>2</sub> flux measurements (Dong *et al.*, 2021) during the workshop helped me disseminate my findings to a broader audience. In addition, I was able to gain new insights and expand my network through discussions with scientists senior to me.

### References

Dong, Y.X., Yang, M.X., Bakker, D.C.E., *et al.* (2011). Uncertainties in eddy covariance air-sea CO<sub>2</sub> flux measurements and implications for gas transfer velocity parameterisations. *Atmos. Chem. Phys.*, 21(10), 8089–8110. <https://doi.org/10.5194/acp-21-8089-2021>



**Iwona Niedzwiecka** is an oceanographer at the Institute of Oceanology, Polish Academy of Science since 2014. She specialises in CO<sub>2</sub> dynamics by leading projects and analysing atmospheric interactions using the bulk method and artificial neural networks. Currently, she heads the WP3 package (determination of the variability of air-sea CO<sub>2</sub> fluxes) in the SURETY (Effect of organic matter SURface layer Enrichment on air-sea gas transfer velociTY) project, where she is focusing on CO<sub>2</sub> exchange via eddy covariance from research vessels.

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Most of the conferences and thematic meetings bringing together the entire community of air-sea interactions, is needed and should take place as often as possible. However, there are several approaches to solving gaps in knowledge about air-sea exchanges, or how to solve problems with different approaches, and in order to be able to talk and solve problems in a larger group, we must first solve them within smaller specialist groups, from the micro to the macro scale. For this reason, this meeting in London was necessary, needed, eagerly awaited by many, clarifying many ambiguities, inaccuracies, showing the future direction of EC research, and deepening the knowledge that can be shared with the general air-sea community during conferences and meetings. For me, as someone new to the field of direct EC measurement, this workshop was one of the best! Due to the fact that the presentations were only an introduction to the discussion panels, the meeting was based on long, substantive and reliable discussions that answered most of the questions

and difficulties posed. For example, during the meeting, the steps in processing EC data for both ship and tower measurements were defined, which will be very useful and helpful for all researchers starting EC measurements as an EC community, we determined the reason for the discrepancy in the results of direct air-sea fluxes, also important points were identified to calculate EC fluxes. This workshop has shown that a lot of work has been done in separate groups collaborating on international projects, so that the big differences in the variables have been resolved, and now the EC community needs to focus on the most important small ambiguities and differences. During the EC meeting, many of my doubts were clarified, my knowledge was ranked, it showed that some of the things I am facing are not a problem in my understanding of the topic, but general problems that we are all working to solve as an EC community. I am very grateful for this meeting, thanks to it I can move forward, and I hope there will be more meetings of this type.

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