

Author Comment with regard to:

Air-Sea Fluxes of CO₂ and CH₄ from the Penlee Point Atmospheric Observatory on the South West Coast of the UK

by M. Yang et al.

18 April, 2016

Many thanks for the thoughtful *comments and suggestions from the Anonymous Referee #2*. We are very glad to hear that the referee found our contribution valuable. Below we present each comment (in *italic*), followed by our reply. All of our replies are incorporated into the revised manuscript where appropriate, unless indicated otherwise.

Summary and General Comments: *Yang et al present the first eddy covariance measurements of air-sea exchange of methane, a significant advance in the field. The manuscript outlines the detection limit for the flux measurements using a Picarro cavity ringdown instrument. In addition, Yang et al present coincident CO₂ flux measurements to make the argument that the Penlee Point Atmospheric Observatory (PPAO) is a uniquely situated for EC measurements of air-sea exchange in coastal regions. In general, the paper is well written and is of appropriate length for ACP. The novel elements of this manuscript center around the CH₄ EC flux assessment. I recommend the paper to be published after the authors attention to the following minor comments.*

Specific Comments:

Page 1 Line 15: Perhaps define quantitatively “reasonable agreement” as this forms the foundation for the argument of PPAO as a site for future air-sea exchange measurements. Thanks for the suggestion. Judging mainly from the momentum transfer observations (and also the sensible heat flux comparison when the mast was fully raised), air-sea flux measurements at PPAO during southwesterly winds are in the mean within 20% of the open ocean air-sea transfer rates. This figure has been included in the revised manuscript.

Page 1 Line 20: Why are the fluxes listed in order of 15, 27, 18 m.

Chronologically the measurements were made at these mast heights. However, for easier reading we have listed the heights sequentially in the revision.

Page 1 Line 23: I encourage the authors to remove the “~” for the detection limits. This should be a calculation where the detection threshold is defined for a specific averaging time, not an approximation. If there is unconstrained uncertainty, perhaps state an upper limit?

Agreed. We have removed the ‘~’ sign.

Abstract: The abstract sells short the novel elements of the CH₄ air-sea flux determinations. I encourage the authors to conclude the abstract with a more definitive statement that puts these new measurements in the content of what was known prior.

Thanks for the suggestion. We have re-written the latter part of the abstract which now reads:

“We report, to the best of our knowledge, the first successful eddy covariance measurements of CH₄ emission from a marine environment. Higher sea-to-air CH₄ fluxes were observed during rising tides (20±3; 29±6; 38±3 μmole m⁻² d⁻¹ at 15, 27, 18 m AMSL) than during falling tides (14±2; 21±5; 22±2 μmole m⁻² d⁻¹, respectively), consistent with an elevated CH₄ source from an estuarine outflow driven by local tidal circulation. These fluxes are a few times higher than the predicted CH₄ emissions over the open ocean but are significantly lower than estimates from other aquatic CH₄ hot spots (e.g. polar regions, rivers and lakes). Finally, based on observations at PPAO, we found the detection limit of the eddy covariance CH₄ flux measurement to be 20 μmole m⁻² d⁻¹ over hourly timescales (4 μmole m⁻² d⁻¹ over 24 hours).”

Page 3 Line 2: The abstract gives the impression that fluxes were determined at a range of altitudes at the same time, however it is clear here, that the range in altitudes also corresponds to a range in sampling periods. This should be noted in some fashion in the abstract?

We have replaced the following sentence “Measurements from the southwest direction (background marine air) at three different sampling heights (approximately 15, 18, 27 m above mean sea level, AMSL) in three different periods during 2014–2015 are shown.”

with..

“Measurements from the southwest direction (open water sector) were made at three different sampling heights (approximately 15, 18, 27 m above mean sea level, AMSL), each from a different period during 2014–2015.”

Page 4 Line 20: More detail on the bias correction should be included here. Is this a general result for all windmaster pro's? Is the value set by comparison to the G3? Or was this number from Gill?

The values of this bias correction are recommended by Gill. The manufacturer describes this as a firmware ‘bug.’ We refer the reviewer to the now published technical note and have changed the manuscript text accordingly:

http://gillinstruments.com/data/manuals/KN1509_WindMaster_WBug_info.pdf

Page 5 Line 1: Is the 5 slpm, 2m subsampling line still turbulent? If not, how important is this?

Yes flow in the 1/4 inch outer diameter (1/8 inch inner diameter) subsampling line is turbulent. The Reynolds number inside is about 2400, which exceeds the threshold number of 2000 for turbulent flow.

Page 5 Line 9: Why is “ambient mixing ratios” in quotations? Presumably this refers to ambient absolute humidity?

The Picarro instrument reports volumetric mixing ratios of CO₂ and CH₄ with respect to 1) measured air and 2) dry air (i.e. measured air with the humidity numerically removed). We referred to the former (i.e. ambient mixing ratios) in quotations here because in our

setup the Picarro was sampling after a Nafion dryer, which removed 80-90% of the humidity already from the sample air stream.

Page 12 Line 8: What is the future prospective for making continuous dissolved SW measurements of CH₄ or other gases at this site? This seems critical for the future success of this site. Can this be done at L4?

Thanks for the comment. The technology is still some ways off from continuous measurements of dissolved CH₄ on the L4 buoy (however there is an in situ oxygen sensor on the buoy). It is fairly straight-forward to take discrete water samples from L4 and/or within the footprint of PPAO and analyze them later in the lab. In the future it might also be possible to install a semi-automated dissolved CH₄ measurement system on Plymouth Marine Laboratory's research vessel *Quest*, which goes past PPAO and on to the L4 station weekly.

Page 13 Line 9: Given that the primary focus of this paper is on air-sea exchange in the shelf region, I think it is most appropriate to state here that PPAO is "... high temporal resolution measurements of air-sea exchange in shelf regions."

Suggestion accepted. Thank you.