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 Anonymous Referee #1*. 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.

Anonymous Referee #1

The manuscript focuses on the air-sea flux of CO2 and CH4 using EC data. In particularly marine EC data of CH4 are previously mainly non-existent making the work highly interesting and worth publishing.

We are very glad to hear that the referee found our contribution valuable.

There are, however, some major problems needed to be addressed before publication. The manuscript is very long, includes many different components and would benefit from being significantly shortened. The new and unique aspect of the manuscript is the marine CH4 fluxes and the paper would benefit from a much narrower focus. The CO2 analysis gives some numbers of the CO2 exchange, but as the water-side measurements are very limited and their representativity for the EC data highly questionable, this aspect of the paper does not bring much additional information compared to existing literature on air-sea CO2 exchange.

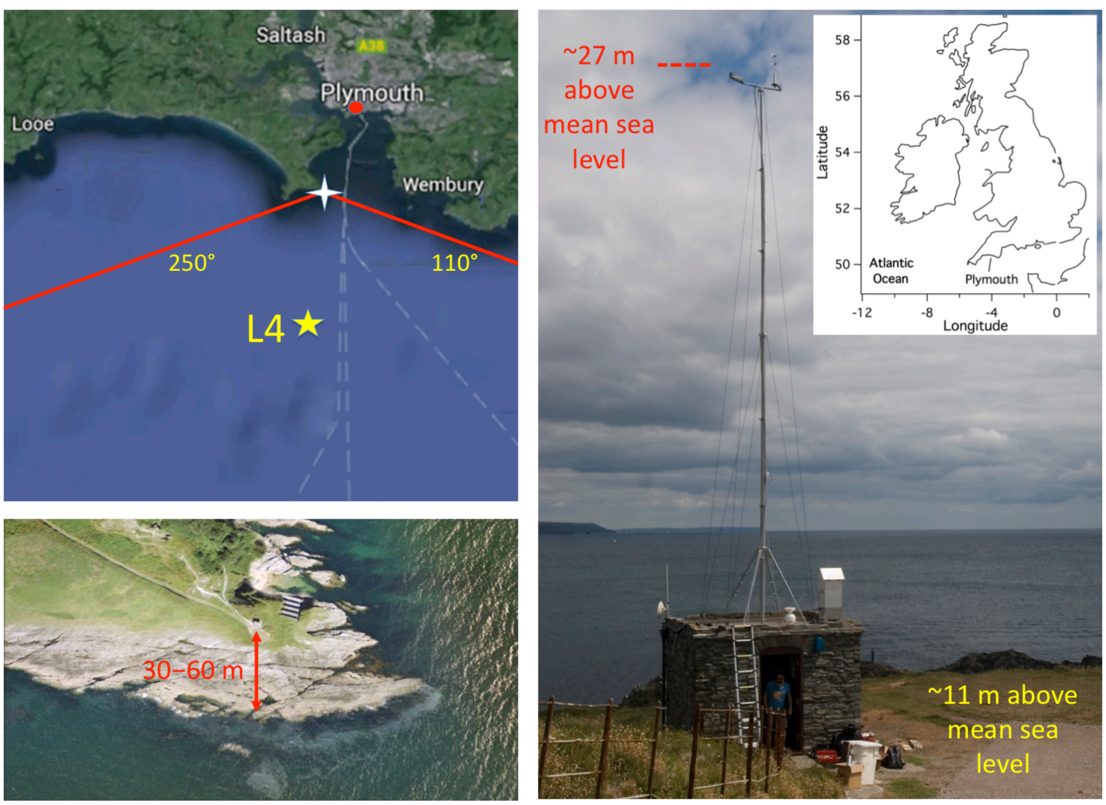
We agree that the manuscript as it stands contains many components. Being the first paper on the Penlee Point Atmospheric Observatory, by necessity it needed to contain some detailed site descriptions and flux data validation. We tend to agree with Reviewer 2 that the paper is of appropriate length for ACP. However, for easier reading, we have restructured the paper slightly and moved the section on the theoretical flux footprint to an Appendix.

We are not in favor of removing the section on CO2 flux all together. Certainly more dissolved pCO2 measurements within the eddy covariance flux footprint would have been desirable. Without such measurements, we tried to verify our EC flux measurements with the best available information. Comparison between EC and predicted CO2 fluxes suggested that our measurements were within reason in terms of magnitude and direction. Additionally the EC measurements demonstrated high temporal variability in CO2 fluxes that are not captured by the weekly pCO2 measurements, which is of value. Finally, CO2 and CH4 were measured using the same instrument and the two gases were subject to the atmospheric turbulence. Thus the reasonable CO2 flux results gave us additional confidence in the CH4 flux measurements.

The authors conclude that the site is suitable for long-term high temporal resolution measurements of air-sea exchange. For such a conclusion a much more thorough analysis is required. The site might be suitable for air-sea exchange representing coastal conditions, how representative the data are for undisturbed non-coastal air-sea exchange is not clear from the present analysis.
We have made our statement more explicit in the revision and changed "air-sea exchange" to "air-sea exchange in shelf regions."

Some more specific questions: Section 2.1: For EC measurements also the upwind topography is of importance, it is not clear from the text or figures how steep the topography is north of the site or how this might influence the measurements.
Land northwest of the site slopes up at an angle of about 9°. In onshore airflow, the mean tilt angle is positive as air is forced upwards. The magnitude of this tilt for southwesterly wind, which blows perpendicularly across the Penlee headland and makes contact with water again to the northeast, is comparable to shipboard measurements.

We have zoomed out on the map in Fig.1 to show the topography more clearly:



Furthermore, a comparison of horizontal wind speed between Penlee and L4 when the wind is from the southwest does not show, within measurement uncertainties, a significant acceleration in the Penlee measurement (e.g. as might be expected when air is forced over a superstructure). So we don't believe the hill to the northwest of the site has a major influence on our measurements during southwesterly conditions.

Section 2.2: The reason for the bias correction of the Windmaster Pro is very unclear and need to be explained.
The manufacturer Gill describes this as a firmware 'bug.' We refer the reviewer to the now published technical note and will change the manuscript text accordingly: http://gillinstruments.com/data/manuals/KN1509_WindMaster_WBug_info.pdf

Section 2.3: Is the signal dried in the Picarro (how does the low pressure of the Picarro exhaust give a dry signal)?
Water vapor permeates through the membranes of the Nafion dryer, while CO2 and CH4 essentially do not. The sheath (i.e. outer) layer of the dryer is filled with the Picarro exhaust air, which is at a low pressure. Thus the pressure gradient between this outer layer and the inner tube (filled with the sample air at higher pressure) drives the water vapor out of the sample air.

Page 11: How is the wave field influenced by the coast and how would this influence the drag coefficient?
Thanks for the question. The bulk of the flux footprint at Penlee resides in waters ~20 m deep. Waves are considered to be in deep water if water depth is greater than half of the wavelength. They start to deviate significantly from deep-water behavior when the depth is less than about a quarter of the wavelength. At a wind speed of 10 m s^{-1}, fully developed wind waves have a wavelength of ~80 m. For wind speeds more than 10 m s^{-1}, wind waves near Penlee could be affected by depth, while swell (which tends to be longer) almost always would be. Thus PPAO should be considered a coastal, rather than a deepwater site. The exact effect of waves on the drag coefficient at Penlee is a topic of ongoing study and is beyond the scope of this paper.

Page 13: SST measured very far away and there is no information at what depth the SST is measured. SST at this distance is probably not very representative for the flux footprint and this will most likely have a large impact on the bulk calculated sensible heat flux in Figure 5.
SST was measured at the L4 station at approximately 1 m below the sea surface. It is true that the SST measurement at 6 km away might not always be representative of the Penlee flux footprint and this contributes to the apparent scatter in the EC vs. predicted heat flux comparison. We acknowledged this in the manuscript. Unfortunately there is no better alternative at this moment.

Page 14: "different atmospheric dynamics" what does this refer to?
Mainly the boundary layer dynamics. It is well known that the boundary layer height changes significantly over land, typically showing a maximum height during the day (due to solar heating of the surface) and a minimum height at night (due to longwave cooling). In comparison, the variability in boundary layer height is expected to be much less over the sea due to the thermal inertia of the ocean.

Page 17: The 10 fold greater detection limit estimated by Peltola compared to the present study is explained by the higher variability over land than over sea. To me the variability over sea (in Figures 10 and 11) also seems relatively large.

Thanks for the comment and sorry we didn't make this point clearer. Here we referred to periods of onshore wind only. As discussed in Section 4.2, ambient variability (1 standard deviation without the noise contribution, after detrending in 10-minute windows) in CH_4 mixing ratio in marine air is as low as 0.2 ppb. In contrast, when the wind is from the north (i.e. from land), ambient variability in CH_4 averages to ~3 ppb. In other words, CH_4 mixing ratio is much more constant is marine air.