

Review 1

General comments: This paper, written by a team led by someone with considerable experience in this field, concerns natural emissions to the atmosphere of methane and other hydrocarbons. As methane is a more potent greenhouse gas than carbon dioxide, it is important that studies providing detailed evidence of natural methane emissions are made available to the scientific community. ACP is clearly a suitable vehicle for this paper.

The paper describes a method of long-term monitoring emissions to the atmosphere of methane derived from natural petroleum reservoirs in shallow waters off the coast of California. This is a valuable method, and could be applied to other natural or anthropogenic methane sources. The Introduction also provides a detailed explanation/ description of natural seabed gas seeps in general, citing numerous relevant sources. Similarly, the fate of methane released from the seabed is also discussed. Whilst this provides valuable context, this material is covered by numerous other papers. There is a danger of the 'context' overwhelming the detail of the method, its application and the acquired results.

Whereas the authors have endeavored to integrate all aspects of a complex study, the paper does not flow well; there are several inconsistencies and other shortcomings that would benefit from more detailed editing.

We agree that the introductory section flow could be improved. To improve the flow, we have moved the approaches summary from the introduction to a new overview section in Methods. We also agree that as the fate and details of how the trace gases cross the water column are not particularly germane to the findings, and thus, Section 1.3 has been deleted with a few relevant citations and sentences added to Section 1.2. OTOH, the results section does seem to flow:

- 1. Field study focus on individual seep areas, which also introduces the reader to the seep field spatial distribution.**
- 2. WCS concentration and wind data and time trends – seasonal and interannual.**
- 3. WCS data patterns related to direction (spatial distribution)**
- 4. WCS data diurnal patterns which discusses how diurnal time and direction trends are not independent.**
- 5. Modeled emissions overall field**

6. Modeled emissions for field sector
7. Sensitivity studies to place the model findings in context
8. Ellwood Field emissions

Although Ellwood Field emissions are somewhat ancillary to the Seep Field emissions; they fell out of WCS analysis, only comprise 16 lines, and are a very interesting discovery (on a regional basis).

Furthermore, although some important conclusions have been drawn, there is no discussion of long-term temporal emission variations, as might be expected from the title.

We have changed the title as the emissions trends are beyond this study. We are well advances on a separate manuscript that investigates these trends; however, adding this work would expand the manuscript unreasonably. We can note that emissions are cyclical with a multi-decadal time scale.

Specific comments:

Lines 138-9: It should be pointed out that, whilst the bubbles from the COP seeps may be oil coated, this is not the case in many (?most) other seeps areas worldwide.

Fair point. Added.

Line 212 - Section 2.1: Would it not be appropriate to identify the type(s) of equipment used to acquire these data (especially the THC)?

Added for winds (MetOne anemometer) and requested from the regulatory agency for THC; however, it will be late-August before this information is available.

Section 4.2.2 Methane and non-methane hydrocarbon emissions. This section is particularly interesting in the light of the implication by Hmiel et al (2020) that pre-industrial natural geological contributions to atmospheric methane are practically insignificant. Can any comment be made about emission trends over the three decades covered by the data reported here?

We have changed the title, removing long term as the trends are beyond this study. We are working on a separate manuscript that goes into these trends. Presenting those findings would double the length of this manuscript, which seems inappropriate. We can state that emissions are clearly cyclical with a multi-decadal time scale.

It would be interesting to compare emission trends with petroleum production - is reservoir depletion reflected by a reduction in seepage emissions? Such a trend is mentioned (Lines 755-778) but only for the Seep Tent Seep.

See above comment. It appears that since production from the western portions of the field ceased, emissions have been above trend.

Technical corrections:

Line 146: "... with dissolved plume concentrations decreasing with time". Time or distance - or both?

Both

Line 151: what is "water-side turbulence"?

Clarified to "Turbulence in the water boundary layer"

Lines 173-4: "COP seep field sources from the South Ellwood oil field whose primary source rock is Monterey Formation, which is immature to marginally mature." This could be re-cast as "The source of the methane of the COP seep field is the South Ellwood oil field, which contains petroleum from the immature to marginally mature Monterey Formation."

Rewritten for clarity as suggested. Also rewrote the next sentence.

Line 191: wet season (singular).

Yes. Thanks.

Line 230: There is no verb in this sentence.

Verb added.

Line 250: "The plume inversion model is a three-step process". Surely this should be "The plume inversion modelling is a three-step process".

Rewritten The plume inversion is a three-step process.

Line 252: What is C'?

C' is the concentration anomaly. Defined.

Line 255: "is fit" should be "was fitted" - although present and past tense seem to be interchangeable in this section.

As the model is in use in many studies and it is now described in present tense.

Line 328: For the benefit of readers, it should be noted that the 'Seep Tent' refers to an installation whereby the natural seabed seepage was captured and utilized along with gas produced from nearby petroleum fields. Suggest moving text from Lines 765-769.

This is a good suggestion, done! Also got rid of another sentence that was duplicated in the process.

Line 367: "almost due south to the". Surely WCS is almost due north of Coal Oil Point?

Yes. Fixed.

Line 373: "allowed far higher values of C and u" - add " to be measured"

Thanks.

Line 437: "C and u for the seep field direction, useep, and Cseep, respectively" should be: C and u for the seep field direction, and Cseep, and useep , respectively.

Thanks, swapped.

Line 450: replace "largely" with "mainly"

Largely on line 458 deleted, largely on line 447 changed to primarily.

Line 579: "A range of approaches are available" - a range ... is available!

Rewritten and corrected from CH₄ seepage to gas seepage (which is what is generally reported).

Lines 665-680 is clumsily worded, and units are mixed (tons - should be tonnes and could be abbreviated to 't' - Gg, Mg and nmol). All previous multi-authored papers are cited using multiple names, except Römer et al. 2017. e.g. Line 666-8: "e.g., summary Römer et al. (2017) where emissions for 12 different seep areas including for sites in the North Sea, Pacific north west, Gulf of Mexico, etc., were 2-480 tons yr⁻¹, multiple orders of magnitude less than seabed emissions for Coal Oil Point. Römer". Poorly worded. Suggest: 'For example, Römer et al. (2017) identified emissions from 12 different seep areas (in the North Sea, Pacific north west, Gulf of Mexico, etc.) of 2 to 480 tonnes yr⁻¹.' [N.B. the last 12 word duplicate the previous sentence. Römer et al. likely used metric tonnes rather than US (Imperial) tons - why not abbreviate to 't?']

This section has been rewritten as we agree it was clumsy. We also added the detail that in Romer et al. (2017) the range of seep emissions are for seabed emissions. We also separated the paragraph between indirect estimates of atmospheric emissions (based on seabed measurements) and direct estimates of atmospheric emissions.

WRT the citation, Schmale et al. (2010), this was an endnote error, and since endnote normally works, it was overlooked. It has been corrected.

Thanks for the correction on units, I have decided to use Mg which has no confusion with American short ton and long ton, and all the US unit backwardsness.

Line 670: Tommelieten should be spelled Tommeliten.

Thanks, Fixed.

Line 693: "emissions were" estimated as ...

Fixed. Thanks.

Section 4.4: to conform to section 4.2.2, emissions should be quantified by mass rather than volume.

Here we use volume as that is how Clark et al. report them, which is now noted.

Line 771: If the Seep Tent Seep is post 1978, how come it was observed in 1970? (Line 768).

This was a typo and should have been 1970 as you noted. The next line about a sea boil was duplicated and is now deleted.

Line 783: "WCS seep emissions" - surely you mean measurements, not emissions.

Revised to "Note, measurement of WCS seep emissions"

Line 1199: If C is defined, then C' should also be defined.

Agreed.

Fig. 4: Why are the rose diagrams plotted with 0 (presumably representing North) at the bottom, South at the top, and therefore East and West reversed from their intuitive places? Also, it would make interpretation of the rose diagrams easier if they were superimposed on the map; this would enable correlations with seep locations more intuitive

We wanted to show the wind rose as if one were standing at WCS looking towards the seep field (the south). Showing all three wind roses on three maps would be unwieldy.

We will break the figure into two figures with the concentration wind rose superimposed on a map and the other two wind roses on the side.